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SALUS GENERIS HUMANI.

THE GLASGOW TEXT BOOKS OF CIVIL ENGINEERING. EDITED BY G. MONCUR, B.SC. M.I.C.E. *Professor of Civil Engineering in the Royal Technical College, Glasgow.*

MODERN SANITARY ENGINEERING

PART I.

With the author's compliments

THE GLASGOW TEXT BOOKS.
EDITED BY G. MONCUR.

MODERN SANITARY ENGINEERING

PART I.

HOUSE DRAINAGE

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PREFACE

Among the many branches of Civil Engineering, that which deals with sewage is now one of the most conspicuous. Many engineering problems are involved in the collection, conveyance, and disposal of sewage; and the present volume deals specially with the first of these, in other words, with House Drainage.

Of the numerous and valuable books on this subject most have been written from the tradesman's point of view. It is easy to find details of how work is usually done, or of how (in the view of the writers) it should be done: it is not so easy to find books which are based on general principles, and which lead from these to practical applications. This is the standpoint of the Civil Engineer, and it differs radically from that of the man whose responsibility is for execution rather than for design.

Some twenty years ago the author was invited by the Governors of the Royal Technical College, Glasgow, to give a course of lectures on Sanitary Engineering, in connection with the Civil Engineering department of the College. These lectures became a regular part of the College work, and have been attended by many other than Civil Engineers. Sanitary officials, architects, building and quantity surveyors, and handicraft workers of the most diverse kinds, have been numerous; and recently, owing to the University recognition of these lectures in connection with Science degrees in Public Health, medical graduates have attended in considerable numbers. The aggregate attendance runs into thousands.

The present volume, while in no sense a reproduction of any lectures, is based on that part of the class work which deals with the sanitation of individual houses; the matter, and the form in which it is put, having been evolved by experience of what has proved most useful to the students.

The opinions expressed are derived from practical and responsible experience extending over nearly thirty years. The earliest four or five of these were given (as Chief Engineer to an active Sanitary Association) almost exclusively to house sanitation, and the remainder to professional work in which sanitation in its various branches has taken a prominent part. The author has therefore no hesitation in expressing his own opinion even when it differs from that commonly held, but in such cases he has felt bound to make it clear that the opinion is an individual one.

G. T.

GLASGOW,
May, 1912.

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MODERN SANITARY ENGINEERING

PART I.—HOUSE DRAINAGE

CHAPTER I

INTRODUCTORY

THE requirements of civilised life have led to the gathering of human beings into communities of greater or less size, and that in turn has led to less healthy conditions of life. The individual is healthiest when his supply of air and water has had no previous human contact, and when the waste products of life are most rapidly dissipated. When numbers are gathered together special knowledge and special care are needed if disastrous results are to be avoided. Sanitary engineering includes all the operations which are necessary to provide fresh air and pure water, and to remove the waste products—particularly those which are to be conveyed in liquid form.

The removal of such waste products has in practice come to be divided into three parts, although these are merely the successive stages of one undertaking. The three parts are :—

1. The collection of the waste matters within the house, and their delivery into the public sewer.

2. The conveyance of the waste matters through the sewers to the place of ultimate disposal.

3. The disposal of these waste matters in such a way as will be in itself inoffensive and will produce a harmless result.

These are known as House Drainage: Sewerage: and Sewage Disposal. The present volume deals with the first, and with those associated matters which it is convenient to consider in connection with it.

Sanitary Engineering is a very ancient branch of civil engineering, but the application of scientific principles to its details is very modern. Even now it is common to find in small communities that the arrangements for sewage conveyance and disposal are of the crudest description, while it is the exception even in the most advanced communities to find anything like a scientific system of house-drainage.

For this there are many reasons. The arrangements for the collection of sewage are part of a structure for which the general responsibility rests on another profession; and while architects find that in a large modern building specialist knowledge of various kinds is required, the problems of drainage do not appear to them to be so intricate as some of the others, and are faced with a light heart. In small buildings it often happens that no architect is employed, the builder acting as his own architect. In either case the drainage arrangements are frequently designed merely to conform with the building bye-laws of the district; or if none exist, with the general trend of such bye-laws; or it may be that the quantity surveyor provides such specification as there is, while the clerk of works, builder, and plumber are left to evolve a system of drainage as the work proceeds.

Thanks to the excellent technical education which is now the rule among plumbers, it frequently happens that of all these the plumber is the man with the best knowledge of sanitary principles. That he should have this knowledge is very creditable and very desirable, but it is not desirable that the man who as contractor or operative carries out the work should know its principles better than the man who is responsible for its design and for the supervision of its execution. What is wanted is not that the plumber should have less knowledge, but that the designer and supervisor should have more. If the architect himself has or can acquire that knowledge, good and well; if not, then specialist assistance is needed.

The "**Drainage System**" includes the main drain and all its branches, from the connection with the public sewer (or other

termination) to the various points where the sewage matters originate; and the proper design of this system in all its details is the first part of sanitary engineering. While this part—the collection of sewage—is on a smaller scale than those parts which deal with its conveyance and disposal, its close association with the dwelling and its occupants gives it great importance from a health point of view, and the aggregate money value involved is enormous. The dangers to health which bad drainage may imply are now thoroughly recognised, but very few people realise the immense waste of money which is going on every day through incompetent design and faulty construction of house drainage. While the aggregate value is great, the individual cost is comparatively small, and the cases in which the work is either designed or superintended by anyone with special knowledge are a small minority. Such knowledge is not usually possessed by the architect or clerk of works; and the plumber and sanitary inspector, even when they possess this knowledge, are not specially concerned with economy.

In the following chapters the endeavour is to give first a general indication of the requirements of a system of drainage; to deal next in some detail with the special requirements of the different parts, and with the way in which these are met; and then to consider how these parts are to be combined into an effective whole. The intention is not simply to indicate what is the usual practice, but to consider the reasons which have led to that practice; the practice may be superseded by something better, but the reasons remain the same. Nor has there been any attempt to deal with the great multitude of "sanitary appliances" which are produced by numerous makers, except in so far as these may be regarded as types. The illustrations and descriptions as a rule are not of actual and individual examples, but of the general principle. The book does not appeal to those who merely wish to find *how* a thing is done or what appliances are used with no concern for *why*. It appeals to those who desire to know the principles on which their work depends.

Formulæ have been purposely avoided as far as possible. Many of the problems presented in this branch of engineering do not admit of the advantageous use of formulæ. Some are ordinary problems of mensuration; in others, such as the thickness of metal required for ordinary drain pipes, practical experience is a much safer guide than theory; while in others formulæ may be used, but so many variable or imperfectly known data are involved that extreme care has to be exercised in interpreting the results of calculation. The flow of liquid in drain pipes is an outstanding example of the last.

To use formulæ without a full understanding of their origin and meaning is to invite disaster. The late Professor Fleeming Jenkin, who was one of the pioneers in scientific study of the matters dealt with here, warned his students at the commencement of their course against the promiscuous use of "Molesworth"—the collection of formulæ to which successive generations of engineers have pinned their faith—and the warning is as much needed as ever. Formulæ, when they are anything more than purely mathematical, are simply the condensed results of experiment; and unless the nature and application of the experiments on which a particular formula is based are known and understood, the user of the formula may be led into serious trouble.

Differences of Opinion.—There are in sanitary engineering many points on which opinions differ widely. The endeavour has been made to point out the existence of these differences, to give the reasons on either side, and to sum up fairly: and special care has been taken to distinguish between views which are generally accepted and those which are disputed.

Past and future Advances.—The great advances which have been made in the last thirty or forty years are apt to obscure somewhat the progress which has still to be made. During the latter half of that period progress has been relatively slow. Sanitary authorities by that time seemed to conclude that the end of progress had been reached, and the result was embodied in bye-laws which are often accepted as final. As a

matter of fact most of these are seriously out of date, and while they prevent the atrocities of a past age they are no less effective in perpetuating methods which are far from perfect. The sanitary engineer must study root principles, and should regard no tradition as too venerable to be criticised.

CHAPTER II

THE SITE AND SURROUNDINGS OF THE HOUSE

The ideal site is one which is freely exposed to the sun, protected from cold and violent winds without any hindrance to free ventilation, whose soil for an indefinite depth is pure and dry, and which is not close to other buildings. If the proposed house is to be constructed without regard to cost and with a free choice of locality it is possible to have many of these advantages, but as the majority of houses are built under stringent limitations of cost and with a very narrow choice of locality, there is need for considerable skill to make the best of what can be got. In urban districts aspect and soil are usually subordinated to considerations other than sanitary, and even in rural districts it is seldom that sanitary considerations are supreme.

Town Planning.—Town planning is beyond the scope of this volume. It has passed through many stages, and the gradually increasing powers of local authorities deal for the most part only with the future. The congested buildings and narrow streets which have grown up in all large towns and most small ones can only be removed by slow degrees and at enormous cost, and the new powers conferred by the "Town Planning Act" are a development of the powers which in recent years have done much to prevent the further increase of districts which were certain to be slums.

Space.—In streets which are bounded by continuous lines of building, it is important that the width of street and the height of the building should be kept in proper proportion to each other, and that sufficient free space should be reserved at the back. It is a common regulation, where powers for the

purpose exist, that the height of the buildings bounding the street shall be limited in proportion to the width of the street, but no practicable limitation of this kind will prevent dingy streets. As to the free space at the back, regulations are very various: some prescribe that the unbuilt ground shall not be less than a certain proportion of the area covered by the buildings: others say that the breadth of the unbuilt part shall be a certain proportion of the breadth of the building from front to back. It has not been found easy to devise a

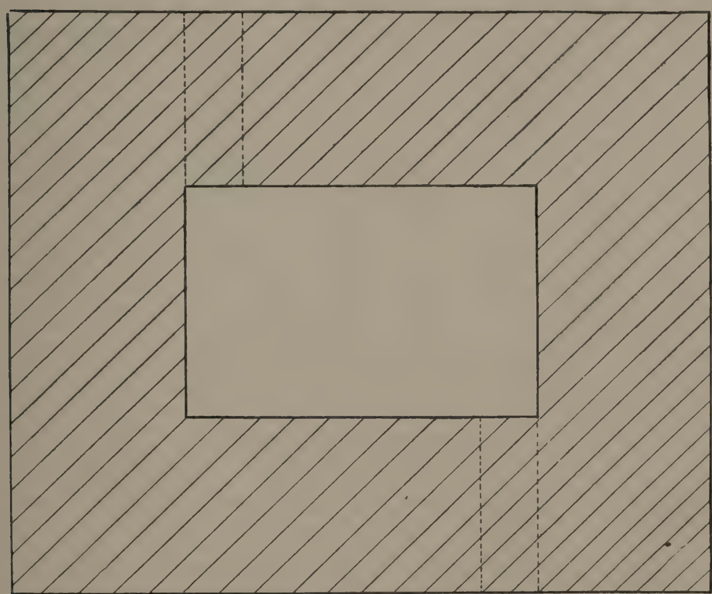

FIG. 1.—"Hollow Square."

rule which is always applicable, and legal decisions have been given which no doubt interpreted correctly what the regulations actually said, but which certainly differed widely from what they were designed to say.

"**Hollow Squares.**"—If houses are arranged in the form of a square or a short rectangle, the proportion of unbuilt area may be very small (Fig. 1), and it will be readily seen that the air inside, which is the only supply for the back windows of the houses,

will be stagnant. If the total area is large the evil effect is slight, but if the houses are high and the area small the contained air may be very impure. The "hollow square" form of construction is now generally prohibited, unless provision is made for the current of air by leaving two opposite corners unbuilt, or built only to the height of one storey, as shown by the dotted lines in the figure.

"**Back-to-back Houses.**"—This system is still worse, and is expressly prohibited by the Housing and Town Planning Act, 1909. The term is not quite free from ambiguity. Its primary application is to two rows of houses, with the back wall common

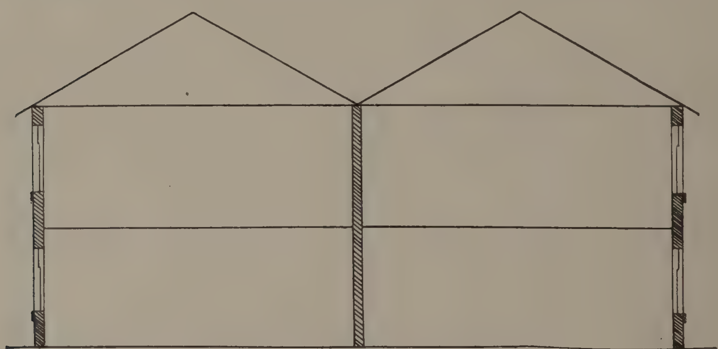

Fig. 2.—"Back-to-back Houses."

to both, as shown in section in Fig. 2. Each house (except those at the ends of the row) has thus only the front available for light and air. The middle wall is unbroken from end to end, and there can of course be no back court. Although the system has been defended on the ground that its cheapness enables a working man to have a better and more commodious house than he could have under any other arrangement, it has been condemned by almost universal consent, on account of the absence of through ventilation. The Court of Session has decided that the term "back-to-back" may be applied to the small houses which are found in the tenements of Scottish towns, where all the windows of one habitation may look to the street and all the windows of another to the back, without

any through ventilation. The "tenement," it should be explained, is the whole building, containing sometimes a large number of habitations.

Aspect.—In no part of the British Isles is the sunshine so much as is desirable, and no part is quite free from biting winds. It is impossible, therefore, to have a site too sunny; and not easy to have it too sheltered. As the sun is in the south and the coldest winds blow from the north and east, these considerations unite in making a south or south-west aspect the most desirable. In a detached house, the architect arranges his plan so that each room has the aspect most suitable for its special purpose, and in laying out new streets something may be done to distribute the advantages as far as possible. For example, a much more even distribution of light is got when the main streets run north and south than when these run east and west. In the latter case, some houses never have the sun on the front, while others never have it on the back. This question of aspect, however, is so mixed up with questions of other kinds, that it calls for nothing beyond a very general reference. Except for the business part of a town it is probable that curving instead of straight lines will be preferred, and for the business streets other considerations will outweigh those of lighting. The natural slope of the ground and convenient access between the different parts, will in every case be the controlling considerations; but the question of healthy occupancy is now fortunately allowed full weight whenever new buildings, of whatever type, are to be erected. The most important of the matters affecting healthy occupancy will next be discussed.

Damp.—It is often necessary to build on a foundation whose character is bad in a sanitary sense, and it then becomes important to make it as good as possible, and to prevent its having an evil effect on the health of the future occupants. The trouble which is most common is dampness, and effective draining is the first requirement. Moisture either in the fabric or in its immediate vicinity is objection-

able, and a naturally wet soil must be dried by artificial means.

Dampness favours the more offensive forms of decomposition and the growth of fungus which may be very destructive, and its evil effect on health is notorious. Even the direct loss of heat is of consequence. The heat needed to evaporate water —the so-called "latent heat of evaporation"—is enormous. It takes more than five times as much heat to evaporate a pound of water without change of temperature as it does to raise that pound of water from freezing to boiling point; and if a house is damp the evaporation of this dampness has the first call on any supply of heat, whether from sun or fires. The result is an excess of water vapour in the air, and lower temperature.

Subsoil Drainage.—A site may be wet either because the soil itself is of a nature which retains moisture or because it lies in a basin of some impervious material. In the latter case all that is needed is to provide an outlet, but in the former close draining is necessary. The drains are ordinary agricultural tiles, set at such a distance apart as the soil may require. In extreme cases they may only be 4 or 5 feet apart. The smallest size which should be used is 3 inches in diameter, and of course if extensive drainage operations are required these will connect with larger drains, not however usually exceeding 4 inches.

Dangers.—Such drains are useful both for removing water from the soil and for admitting air into it, but the very fact that they act in this way introduces a danger which may be very serious and which is very common. They may serve as convenient passages for rats; and unless they discharge into the open air, they may convey foul air from sewers or sewage drains into the subsoil. One of the anxieties of an engineer in re-arranging the drainage of an old house is lest any such (unknown) connection may exist. It is quite common in country houses to find that agricultural drains are laid right round the walls, and freely connected with the main drainage

system. Sometimes a built "air-course" round the foundations is similarly connected. As a rule such mistakes are detected by effective testing, for there are either positive results which prove their existence, or negative results which will indicate to an expert their probability. This will be more fully considered under the heading of "Tests.' It

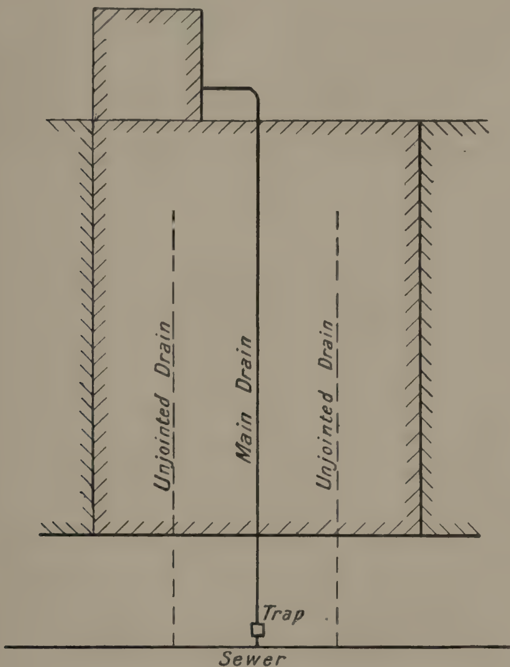

FIG. 3.—A Danger of Subsoil Drainage.

sometimes happens however that misplaced ingenuity contrives an arrangement which no testing could detect. The arrangement shown in Fig. 3 was found by mere accident. The sewer passed close to the house, and the main drain was connected to it by means of a trap in the usual way, but two unjointed or "agricultural" drains, one on each side of the main drain, were in direct connection with the sewer with nothing to hinder the passage of sewer gas into and through them.

About country houses it is not uncommon for subsoil drains to be put in from time to time by the gardeners. Sometimes these drains are in the immediate neighbourhood of the house, and a man who is accustomed to this kind of draining has no conception of the need for tightness. He wants an outfall for his drain, and he finds it very conveniently by knocking a hole in the side of a stoneware drain and sticking the end of his open tile into it. The facts that the stoneware drain carries sewage, that he has made a hole through which gases if not also liquid may escape, and that the end of his drain may obstruct the flow, do not bother him at all; but they may have a serious bearing on the sanitary condition of the house. Incidentally this is an argument in favour of iron drains, which are fairly secure against such treatment.

Open Ends for Subsoil Drains.—Wherever it is possible, all subsoil drains, which from their very nature are pervious, should terminate in the open air. This implies that the ground has sufficient fall to allow their upper ends to be deep enough for their intended purpose, while their lower ends come to the surface. If this can be done, and if provision is made against the entrance of rats, such drains introduce no danger. If that is impossible, it may be necessary to form a connection with the main drainage system, and this is considered later (p. 86).

It is seldom necessary to have such drains actually under the house. If they are carried round the house so as to intercept any water which tends to flow into the site, it is usually sufficient.

It is desirable to have the site of the house well drained for other reasons than the direct harm which the moisture may do. The level of subsoil water rises and falls according to the rainfall for the time being. As it falls, it draws down air into the pores of the soil, and as it rises this air is forced out. But the air so forced out is not the same pure air that was drawn in. It has met with impurities in the soil, and at the best contains a greatly increased proportion of carbonic acid. At the worst it may contain most objectionable con-

stituents, derived from sewers, gas mains, buried refuse, etc. It is thus very desirable that this pumping action of the ground water should be stopped by draining it away at a level which is permanent and sufficiently low.

Damp-proof Courses.—But when all this has been done, it is still necessary to protect the house by interposing an effective barrier between the soil and the inside of the house. This barrier must be effective against both moisture and gases. No preparation of the site and no natural suitability can justify

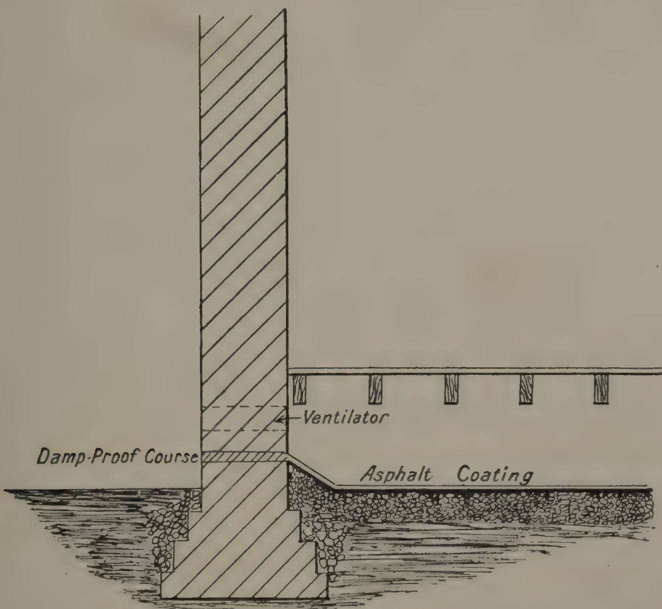

FIG. 4.—Damp-proof Course and Asphalt Coating.

the omission of this precaution. Its form is two-fold—a layer of impervious material right through the thickness of each wall, and a further layer continuous with the first, over the whole area occupied by the building (Fig. 4.). However dry the soil may be naturally, or however well it may be drained, it is not so dry as the interior of the house should be; and however thorough the means that have been taken to ensure the

purity of the site, the ground air is much less pure than atmospheric air. Even in the open country there is danger of polluted ground air; in towns the danger is great. Fatal accidents due to the escape of coal gas from the mains, and its passage through the ground into sleeping apartments, have occurred again and again; and recently several cases of wholesale poisoning have occurred, due, apparently, to the entrance of gases from the sewer. While it is true that many existing houses have been erected without any effective barrier, and that some of them (by no means all) give no proof of being unhealthy, the reason for the precaution is so obvious and so well known that there is no excuse for its omission.

The impervious layer in the wall, commonly called the "damp-proof course" (sometimes contracted to "damp course") prevents the upward passage of water which would otherwise be caused by the capillary action of the porous brick or stone. It forms a part of the wall, and has to support the weight of the house. Strength is therefore an essential feature. Slabs of glazed stoneware are very suitable: they are specially made for the purpose, and may have perforations by which air is admitted to the space below the lowest floor. Natural close-grained stone, such as slate or Caithness pavement, is often used, and the latter in particular (being stronger) is an excellent material. Sheet lead is sometimes employed, not so often in new work as when it becomes necessary to insert such a course in an existing wall. This operation is possible, but it is somewhat tedious and costly, and must be done with extreme care. A hole is cut through the wall, a roll of lead whose width is the same as the thickness of the wall is inserted: the hole is gradually extended and the lead unrolled. The gap left above the sheet of lead is built up close behind the roll, and the work is continued until the whole wall has thus been intersected by the lead. A machine for performing this operation has been introduced by Maple and Co. By its use a half-inch seam is cut in the wall, and after the lead sheet has been inserted the wall is wedged and Portland cement is used to fill the void.

Asphalt materials, which for some reasons are specially

suited for damp-proof courses, have the disadvantage of softness, and consequent liability to be squeezed out. For this reason they are not always recognised as satisfactory by local authorities. There is, however, great variety among these preparations, and in some much has been done to get over the difficulty.

Impervious Covering of Site.—For covering the area occupied by the house, within the walls, asphalt is specially well adapted when the space immediately above is merely an air space, that is, when it has not to stand traffic. Asphalt is much more effective than concrete in preventing the passage of water or gas, but its softness makes it desirable that it should be laid on some firmer material, such as a layer of well-rammed broken stones, or even on a concrete foundation.

Sunk Flats.—If damp earth is allowed to be in contact with the outside of the wall above the damp-proof course, the advantage of the latter is largely destroyed. This sometimes happens through carelessness, but it is sometimes also due to "sunk flats." It is, of course, undesirable that any habitable part of a house should be sunk below ground level, but in towns this is sometimes unavoidable. When these cases occur two such courses may be used, one below the lowest floor level and the other above the highest ground level, the outside of the wall between the two courses being faced with impermeable material; but it is still better to construct an airspace outside. If such an area is open to the sky there is little danger from it, but when it takes the form of a covered air channel it is not nearly so effective, and its possible connection with some drain must not be forgotten. The impermeable facing should be in addition to such an area, and not in substitution for it.

CHAPTER III

THE GENERAL PRINCIPLES OF DRAINAGE DESIGN

Definitions.—The channel by which the liquid refuse is removed from a single house is called a drain; when it serves for more than one house it is called a sewer. Both in common language and in law this is the broad distinction; but the application of this distinction in specific cases has been the cause of immense litigation. This, however, is not a matter which falls to be dealt with here.

House drainage means the removal of all the refuse material which is either in itself liquid or which is made practically liquid by the addition of water. It is usual to regard this refuse as divided into three classes, and to consider three different sets of pipes, each requiring different treatment. The channels which convey excretal matters are known as "soil" drains and pipes. The "waste" drains and pipes, conveying the water which has been dirtied in sinks, baths, lavatory basins, and tubs, form a second class; while the rain-water drains and pipes form a third. In each case the "drain" is the part, nearly horizontal, which is underground; the term "pipe" being applied to the part, usually vertical, which is above ground, although as a matter of construction the drains also are formed of pipes. The descriptive name, "soil," "waste," or "rain," is that of the most objectionable or dangerous of the substances conveyed by each pipe. Thus a drain is a "soil" drain if it connects with even one closet, no matter how much waste and rain water it conveys; and the connection of a single sink makes a drain a "waste" drain, although it chiefly carries rain-water.

Classification.—The usual practice is to consider that waste pipes and drains require less stringent treatment than soil

pipes and drains; and although it is open to question (see p. 64) whether this has not been overdone, the distinction is for many purposes convenient. Rain-water is less objectionable than either of the others, and sometimes is kept out of the main drainage system altogether. While most towns are sewered on the "combined" system—that is, the sewers receive all the rain-water—there are some which are sewered on the "separate" system, and it is then essential that each house should send out its rainfall in a drain distinct from that which is to connect with the sewer. It sometimes happens, too, especially in the case of institutions and other premises occupying a large area of ground, that for reasons of convenience or economy the internal drainage is on the separate system, even if both drains discharge into the same sewer. As a rule, however, the main "soil" drain of the house is the channel which conveys everything; all the branch drains of every description—soil, waste, or rain—converging into it.

Object and Conditions of Drainage.—The drainage system has to fulfil a certain purpose, and it must do so under certain conditions. A clear knowledge of that purpose, and of those conditions, is the first step towards its proper design. The purpose is to collect all the sewage matters at their various places of origin, and to convey them to the sewer or other place of disposal at once and without loss. It deals with substances which may generate offensive or noxious gases: these also must be prevented from escaping except at places provided for that purpose. Its material, therefore, must be both water-tight and air-tight, and its internal surface must be smooth, so as not to hinder the flow of its contents. It is exposed to accidents of various kinds, which may cause either internal or external pressure: it must therefore be strong enough to resist any reasonable pressure without being injured. It must not be subject to corrosion by the action of anything with which it may naturally come into contact, such as the earth in which it is buried or the substances which may pass through it. Its gradient must be such that gravitation

will produce a suitable velocity of flow; and its size must be just sufficient to carry off promptly the maximum quantity of liquid.

Pipes and Joints.—The only method of construction which has so far been devised is that of using pipes, joined together to form the channel. It is the complete system, and not the individual lengths, to which the above requirements apply, so that the joints as well as the component parts must comply with them. If that is impossible, the material is not satisfactory, however suitable the individual parts may be.

With the exception of the rain pipes, the whole drainage system is included in these requirements. In the rain pipes the need for air-tightness does not exist, so long as effectual means are taken to prevent gases generated in other parts of the system entering them.

Trapping.—The drainage system forms a connecting channel between the sewer and the house. The sewer contains "sewer gas"—an indefinite substance of unknown power for evil, but which no one wants to admit into his house. The drainage system itself is inevitably fouled by the passage of offensive matters, and it contains air or gas which must also be kept from entering the house. There are differences of opinion as to the degrees of danger from sewer, drain, soil pipe, and waste pipe; but everyone is agreed that gases from even the least objectionable should be kept outside the house. It is further agreed that a barrier for this purpose should be interposed at the extreme upper end of each branch of the drain, that is, at the point where the sewage matters enter the pipe and disappear from view (see p. 62). From that point downward the channel is not accessible for ordinary cleaning, and must therefore be cut off from all direct connection with the interior of the house. Whether or not there should be other barriers, dividing the sewer from the drain and the soil pipes from the waste pipes, is a question to which different answers may be given; present-day opinion is less strongly in favour of

detailed "disconnection" than was the case a few years ago, but it is still in use to a considerable extent.

What is desired is something which will allow a perfectly free flow of liquid, but which will form a complete barrier to the passage of air or gas. This in its fullest extent is unattainable, but the water trap has been universally accepted as a sufficient equivalent. The other devices, either instead of the water trap or in addition to it, are so few in number as to be almost negligible. The theoretical and practical efficiency of the water trap is discussed in Chapter VIII.

Ventilation.—Through ventilation is regarded as an essential of good drainage. A trap interrupts this, and so it becomes necessary to provide means for the admission and outlet of air at each end of each section of the system. In particular, when a trap is placed close under every fitting in the house, it is important to continue the soil or waste pipe right on to some place where it can discharge foul gases without offence, the connection from the fitting coming in as a branch. It is no more desirable to have stagnant air then to have stagnant sewage in the system; the leading principle in design is to ensure on the one hand that nothing from the pipes can get into the house, and on the other that the pipes themselves and the air which they contain shall be as clean and fresh as possible.

The requirements of a drainage system thus involve, in addition to the individual fittings, the choice of material for pipes and joints, the calculation of gradient and size, questions of trapping, and methods of ventilation. These will be considered in further detail.

General Considerations.—There are, however, general considerations of design, apart from all these, which have to be kept in view. They are less definite and specific than those already mentioned, but they are not of less importance. The difference between a skilful and an unskilful design is nowhere more conspicuous than in the way of dealing with these general requirements; the rule-of-thumb designer will produce a system complying with all the stock requirements, but which

is elaborate, clumsy, and extravagant; the designer who is at home in his work will produce a better result with simplicity and economy. Skill cannot be taught by rules, but a statement of what should be aimed at and avoided may be of assistance. It will be seen that some of the desirable features conflict with each other, and that compromise is frequently needed.

The drains should run in straight lines from point to point, vertically as well as horizontally. Where the direction has to be changed, it should be at a place where inspection is easy, the means of inspection being provided by manholes.

The length of pipe should be as little as possible. Every foot of pipe is a potential danger.

The traps should be as few as possible. At best they are a necessary evil, forming a certain obstruction to the flow, and holding back part of that very substance which we wish to hurry away.

Parallel lines of pipe should never be used needlessly. The less the flow in any given pipe the more difficult it is to keep clean.

No part of the system should be exposed to pollution unless it is also exposed to a cleansing flow (see p. 62).

When branch drains are trapped from the main, the trap should be as close as possible to the main. Otherwise the part of the branch between the main and the trap is unventilated, or it requires a special air pipe. Either of these suggests bad design, though a few feet of unventilated drain is not a very serious flaw.

Outside or Inside Pipes.—It is usually assumed that all pipes conveying soil or waste water should be outside the house so far as is practicable. Many local bye-laws and building regulations insist on this. There is not, however, any necessary danger connected with properly constructed inside pipes. Other things being equal, it is no doubt better that all such pipes should be outside, but it is quite easy to carry this principle too far. It would often be better to have a short drain

through a house than to have a long drain round a house: the former would not only be shorter, but would have fewer bends and a better gradient. The question as affecting soil and waste pipes is discussed on p. 98.

Consideration of Cost.—Efficiency is the first consideration, but there is no reason why economy should be disregarded. There is a certain standard of quality which the drainage system of the poorest house should reach if it is to be thoroughly efficient, and no higher standard is possible in the drainage system of a palace. So far as drains, soil pipes, and waste pipes are concerned, the best quality ought to be required in every case; anything less is a sacrifice of real economy to apparent cheapness. The sins of the jerry builder have created a feeling that economy is only to be reached by scamping, and the extravagance of some so-called sanitary reformers has caused a feeling that good work is hopelessly expensive. Neither of these opinions is well founded, and the capable designer will avoid both extremes. He will insist on material and workmanship of the highest class, but he will so dispose of this material and workmanship that much less will be required than if the design were less skilful. A high-class system skilfully designed will often cost less than haphazard design and shoddy workmanship. Economy in material means a direct increase in efficiency. The best system is the one which accomplishes its purpose with the least material. The selection of fittings is an entirely different matter, and while sound and useful fittings may be got cheaply, extra cost usually means equal soundness and utility, combined with finer appearance or greater convenience. In this direction there is quite properly room for great diversity.

It is easy to state these general principles, but for their application it is necessary to have a practical acquaintance with the materials which are available for the different parts of the system, and with the fittings which the manufacturer places at the disposal of the designer, as well as with the natural laws on which the working of each part is based. Before pro-

ceeding to work out any problems of design, it will be necessary to consider the numerous details of which the complete design must be composed.

The chapters immediately succeeding will deal with such details, the working out of the design being deferred until these have been considered.

CHAPTER IV

MATERIAL FOR DRAINS

DRAINS are invariably made of pipes, and for these pipes three materials are in common use. These are stoneware, fireclay, and cast iron.

Stoneware and Fireclay.—The general character of the first two is the same, both being produced by moulding and burning the plastic material. The required temperature is higher in the case of fireclay, and the tendency to twist or warp is accordingly greater. As a result, fireclay pipes are in appearance rougher and coarser than those made of stoneware, and they are frequently regarded as being simply an inferior variety. This, however, is not necessarily the case. While it may be true that there is a greater range of quality in fireclay than in stoneware, and that the poorest class of fireclay is worse than the poorest stoneware, it is quite possible to produce fireclay pipes which are in all essential qualities quite equal to high-class stoneware. In a series of comparative tests which the author had occasion to make some time ago, using first-class pipes of each kind, the fireclay pipes gave better average results in resistance to internal pressure, weight carrying, and non-porosity.* The stoneware pipes on the other hand gave more regular though lower results, and in symmetry of shape were distinctly superior. The lesser porosity of the fireclay pipes was probably due to the "slip glaze" with which they were internally coated, and for the same reason the inside surface was distinctly smoother. Fireclay pipes are made in 3-feet lengths, as against the 2-feet which is usual with stoneware, and this is of advantage in reducing the number of joints. Assuming that care is

* See Appendix, note A.

taken to select the best quality of either material, there seems no inherent reason for using one rather than the other, and the choice may well be determined in any given case by local considerations, not the least of these being the price at which they can be put on the ground.

Jointing (Ordinary).—The ordinary joint is that shown in Fig. 5, one end of the pipe being plain and the other having a socket into which this is introduced. The material almost invariably used for jointing is Portland cement mortar. Clay and lime, which used to be common, are entirely unfit for the purpose. For some special joints the Portland cement is used not as mortar but as "grout," that is, it is mixed with so much water as to be almost liquid, and is poured into the joint. It is then commonly used "neat" with no mixture of sand: but for mortar, sand is usually added. The addition of sand makes weaker mortar, but makes it less liable to crack, and on the whole is an advantage. The saving of cost effected by the use of sand is so trifling in an ordinary drain job that it need scarcely be considered, but it may readily appeal to a dishonest contractor, and it is of course much easier to make sure that no sand is used than to see that a stipulated quantity is not exceeded. Half-and-half by measure is the weakest mixture that should be allowed for drain jointing.

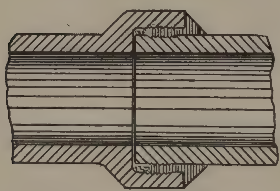

Fig. 5.—Spigot and Socket Joint.

Cement.—The total amount of cement used on the job may be very trifling, and therefore the precautions as to quality, such as are a matter of course on large works, may be impracticable. When only a few bags of cement in all are required, they are got from the builder's or dealer's stock, and it is not impossible that this may contain cement which has not met the requirements of some large contract and has so been rejected. Such cases are not unknown. The best that can be done usually is to insist on a well-known brand.

The ordinary joint may be made with mortar alone, but it is a common custom to first drive in a ring of oakum or yarn—either tarred or soaked in liquid cement—for the double purpose of "centreing" the pipe and ensuring that no cement gets into its bore. The oakum or yarn itself may project into the pipe, and care should always be taken to look through the drain after the joints have been made, and see that nothing has got in to obstruct it (see Chapter XXII).

Special Joints.—Numerous joints have been devised for the purpose of securing the above advantages without the use of oakum or yarn, which are of course perishable materials, and at the same time of retaining the simplicity of the ordinary joint. The following may be mentioned: The Hutchison joint has a shoulder in the socket (Fig. 6) so that beyond the part which is to receive the cement there is a further and narrower part into which the end of the pipe enters and fits somewhat closely. The cement mortar is readily pressed into the outer part, but to get into the inside of the pipe it has to pass through the narrow space at the end, and this makes its entrance somewhat difficult. The Fitzpatrick joint (Fig. 7) has the ends made with a taper resembling roughly a turned and bored joint, and has besides an apron in front of the socket to retain the cement. A third method is to have projections moulded on the inside of the socket, as in Mansfield's joint (Fig. 8). The first of these is the most likely to keep cement out of the pipe, but on the other hand it requires more accuracy in manufacture, otherwise the small clearance will not allow

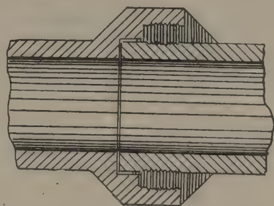

FIG. 6.—Hutchison Joint.

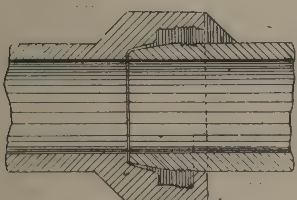

FIG. 7.—Fitzpatrick Joint.

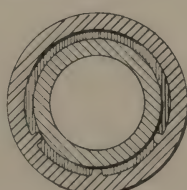

FIG. 8.—Mansfield Joint.

the spigot to enter at all. Whether or not this is an advantage depends on the point of view.

Jointing in Wet Trenches.—When the trench is free from water, the laying of pipes with any of the foregoing or similar joints presents little difficulty. But when a drain is to be laid in a wet trench, the difficulty of making the joints and protecting them from water until they have set may be very serious. To meet this difficulty, two distinct types of joint have been devised.

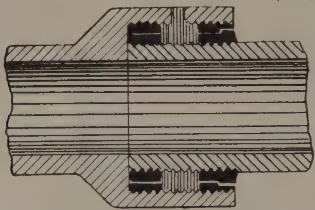

Fig. 9.

One of these has been already alluded to, as being made with Portland cement "grout." The two pipes are so shaped that when they are brought together an annular space is left, and into this the grout is poured. The meeting edges of the pipe require to be water-tight in order to retain the grout, and this is accomplished either by having them faced with some permanent composition, usually bituminous, or temporarily by a rim of puddle clay. Fig. 9 is an example of the one, and Fig. 10 is an example (interesting as being an early type) of the other.

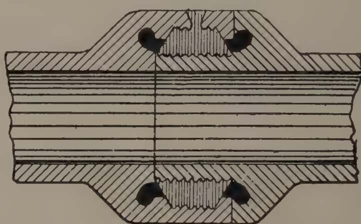

Fig. 10.—Joints made with Cement Grout.

The other type depends for its tightness on the true meeting of the special composition. Fig. 11 illustrates the general principle, different makers adopting different shapes. The composition is applied

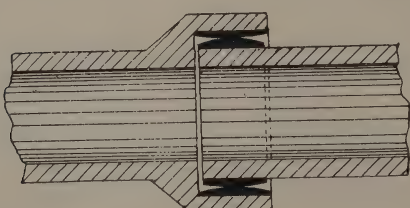

Fig. 11.—Composition Joint.

both to spigot and socket, and in one of the best-known forms the former is rounded and the latter cylindrical, so as to produce more or less a ball-and-socket joint. A more recent development is to have cement outside this joint, applied either as mortar, or as grout retained by a canvas band—the latter requiring an extra flange. Joints joined by fusion have also been introduced.

Importance of Simplicity.—As a matter of practical expediency, it is always desirable to use the simplest material. In carrying out any work, the number of bends, branches, inspection openings, and other "specials" is very considerable, and the exact requirements cannot always be foreseen. This is specially the case when old drains are being replaced, and when plans for the new work have to be completed before the ground is opened to any extent. In such circumstances unexpected developments often occur, requiring modifications of plan, and if a joint is used that will not upon occasion "range" with ordinary pipes very serious delay may occur. Even in the case of new buildings it may often happen that the drainage plan has to be revised on account of some change quite unconnected with drainage. In any case a pipe may be accidentally broken. When therefore it is necessary to use the more elaborate forms of jointing more care is required to make sure in advance of what will be needed, and it is well to restrict the special joints (especially those which will not range as above) to work where they are really required. It is very awkward, and may be very costly, to find that a job is completely stopped because the maker of the patent joint has not in stock the particular pipe which is suddenly wanted.

Cast Iron.—Cast iron pipes are now used to a large extent for house drainage, but they are still in a small minority compared with the materials already considered. In many places they are almost unknown. They had been used in isolated cases thirty or more years ago, and by 1883, when attention, apparently, was first publicly called to their advantages, they had been in use long enough to prove their worth.

The credit of their introduction, however, goes much further back, and probably belongs to some unknown plumber. The author is inclined to give it to Mr. William Connell, who carried on business as a plumber in Glasgow from 1838 to 1898, and who certainly used iron drains as early as 1876. The pioneers had to use water pipes (sometimes stove pipes for the larger sizes), as special drain pipes were then unknown. Before long, however, special drain pipes, traps, inspection pipes, and the like, were readily obtainable, and the catalogues of the various foundries which specialise in this class of work have shown a steady increase in the variety of stock castings. In their main features, too, iron drain pipes and fittings have become standardised by common practice. The system of vertical casting has never been generally adopted, as it has in the case of pipes for water supply, and it sometimes happens that irregularities in thickness or even holes are found. In practice this danger is met by making the pipes fairly thick. For all diameters up to six inches the usual thickness of metal is three-eighths of an inch. Six-inch pipes are made either of this thickness or half inch. The pipes have thus considerable strength, and the sockets or faucets have thickened rings to withstand the strain of "caulking" or "staving."

Jointing with Lead.—The jointing is practically the same as in the case of water pipes—a partial filling of oakum or yarn, for drain purposes often soaked in red lead, is driven hard in, and outside this a ring of molten lead. The contraction of the lead in cooling necessitates a further operation, and by the use of the caulking tool and hammer the lead is driven hard into the joint and so expanded laterally. An uncaulked lead joint would not be air-tight even under a very slight pressure, and would not even be water-tight against any considerable pressure.

Although this joint has been universally employed in connection with waterworks as well as drainage works, it has two disadvantages. The vegetable material which forms the basis of the joint is to a large extent perishable, and the caulking effect does not go very deep into the lead. It is doubtful

whether in average joints the lead is in hard contact with the iron more than a quarter of an inch from the surface, and it is therefore on this quarter of an inch that the tightness of the joint depends. Various methods have been adopted to improve upon this state of matters.

Special Forms of Lead Joint.—Instead of oakum, strips of lead have been used as the foundation of the joint, these being caulked in so as to leave a cavity for the molten lead. A further development is the use of "lead wool," which is lead cut into threads, loosely woven together into strands. Strand after strand is packed into the joint, each strand in succession being thoroughly caulked. A still more recent device is "ribbon lead," the lead being thrown off a drum in the act of solidifying. To make a good job more vigorous treatment is needed than in the case of an ordinary joint, but skilled workmen can attain very good results. If for the sake of economy yarn or oakum is used in any form of lead joint, it is important to see that it is not used in excess. The lead should not be less than an inch in depth, even for the small pipes used for drainage.

Protective Coating.—Iron can never be used for any structural purpose without some protection from the air. Its affinity for oxygen is so great, and the ordinary red oxide or rust is chemically so unstable, that the whole mass is gradually converted into this red oxide. The surface rust gives up some of its oxygen to the metallic iron below, and itself draws more from the atmosphere. To prevent this, such articles as pipes are either coated with some foreign substance, or a layer of black oxide is artificially formed over them. The latter process is usually called "barffing" from the name of the inventor, and consists in the treatment of the articles while hot by superheated steam. This process is, however, comparatively uncommon. The usual coating is (1) the so-called "galvanizing" or zinc coating; (2) the bituminous covering known as "Smith's solution"; and (3) "glass enamelling."

Galvanizing is for this purpose not common. The thin

coating of zinc is no very effective covering, and it is not well adapted for permanent work.

"*Smith's solution*," invented by the late Dr. Angus Smith, is by far the most common. The trade description "coated" means this particular coating, although it is desirable in specifying to be more precise. The coating (a compound of oil, pitch, and tar) should be applied hot and to hot pipes; that is, the pipes should be plunged while hot into a hot bath of the material. They should of course be clean and free from rust, and the resulting coating should form a glossy black varnish, smooth and uniform, over the inside and outside of the pipe. In small water pipes trouble is often experienced from defective coating. This seldom occurs except in the smallest sizes (under 3 inches), and is practically unknown in the case of drain pipes. It is probable that the greasy matters carried in ordinary sewage, combined with the facts that sewage does not contain much free oxygen, and that the pipes are large enough to be easily coated, account for this immunity. It is said that certain soils have a strong corroding action on the outside of such pipes, but this is certainly uncommon. Drain pipes known to have been laid for twenty or more years are often taken up in good condition.

Glass enamelling is a much more recent means of protection. The object is to produce a skin of glass on the iron foundation, and this is accomplished by making a glass mixture, termed in the works "frit," which is either ground with water and applied as a fine paste, or applied as powder to the metal surface. This mixture fuses into a true glass, but so far as the author knows, no maker has succeeded in producing a glass which will withstand the action of corrosive substances as ordinary glass will. Apart from that, however, the glass surface is extremely smooth and clean, and, so far as can be judged in the comparatively short time since its introduction, it gives very satisfactory results. It costs considerably more than simple "coating"—on an average it may be said to add about 50 per cent. to the cost of the pipes—and when the glassy surface is cracked or broken, so as to expose the metal beneath, the protection is gone. This introduces a difficulty

when pipes have to be cut, as it is scarcely possible to avoid some exposed surface at the cut end. The process of glass enamelling is more or less a trade secret, each manufacturer having his own special formula. It is doubtful whether under ordinary circumstances the extra cost of glass enamelling drain pipes is worth while, although where very flat gradients are involved, and where therefore it is important to have the utmost smoothness in the channel, the case for glass enamel is stronger. Sometimes, for no very apparent reason, the visible parts such as inspection openings and traps are glass enamelled, while the main lines are coated. Uniformity would appear to be better practice.

Choice of Material.—There are thus three materials from which to choose in constructing a system of drainage. The choice between stoneware and fireclay is less important than making sure that whichever is used is of the best quality. Of the two, that may safely be preferred which (in its best qualities) can be delivered at the required place at the cheaper rate. To some extent this might be modified by other circumstances. For instance, a particular form of joint may suit the conditions best, and it may only be available in the one or the other material, but in ordinary circumstances there is no reason for incurring extra cost for the sake of having one rather than the other.

The choice between either of these and iron is a more serious matter. An iron pipe is of itself much stronger, and admits of much more effective jointing than either of the others. Stoneware and fireclay are rigid and brittle, they will crack rather than bend, and cement joints are easily damaged. Once the joint is damaged it cannot be effectively repaired except by picking it out and re-making it, and the attempt to do this will probably break the pipe. There is a chance, too, that unskilled labour may be employed, and negligent work or deliberate scamping is difficult to detect. Numerous cases have been reported where drains which have been laid and then passed as satisfactory have been condemned when tested a year or two later; and the unreliability of the material is

indicated by the usual bye-laws, which not only insist on a concrete foundation, but in the case of drains through a house, a complete sheathing of concrete.

The practical conclusion is that while stoneware or fireclay pipes are excellent for any purpose where air-tightness and water-tightness are not absolutely required, it is unsafe to use them when these conditions are necessary. After experiencing the frequent trouble and annoyance of finding leaks in systems to which every care had been given, the author has made it a rule in his own practice to disclaim all responsibility for the tightness of any drains other than iron; in other words, to have nothing to do with drains which are meant to be tight, unless constructed in that material.

Comparative Cost.—The usual arguments against the use of iron for drains are the chance of corrosion, and the cost. The former has already been discussed, but it may be added that where acids are a normal constituent of the flow, iron is obviously an unsuitable material. The wastes from chemical laboratories, for example, should be otherwise conveyed (see p. 193). As regards cost, most discordant statements are made. It is said on the one hand that iron will cost two or three times as much as stoneware or fireclay; it is said on the other hand that the extra cost will not exceed 5 per cent. Both these statements contain some truth. The actual cost of the iron pipe, with traps, inspection openings, and other special castings, may very readily be two or three times as much as the corresponding work in stoneware or fireclay, even when the iron pipes are simply coated. But the laying of pipes implies opening and subsequently filling trenches; and drains must be provided with built manholes and other accessories. The cost of these is practically the same in either case. The iron pipes do not as a rule require the concrete foundation. When all these are taken into account it is probable that the iron drain will only cost 50 per cent. more than the other, and this may be more than balanced by the absence of the concrete sheathing, which is quite unnecessary for iron pipes. Still further, it may be said that the actual drains are only one part

of what may be called the "drainage installation," which includes soil pipes, waste pipes, air pipes, and fittings. If therefore costly internal equipment is added to both sides of the comparison, it may readily happen that the difference in total cost due to the drain material may be a very trifling percentage of the whole. The comparison, however, is necessarily a very vague one; the proportional difference over the whole installation will be much less in the case of a town house covering a small area and with a short undergound drain than in the case of a rambling country house where long drains are needed. In any case, the original difference in cost is negligible in comparison with the cost involved in opening up drains to repair defects which have been discovered, to say nothing of the inconvenience and indirect loss due to the latter; and it should never be allowed to weigh against using the most suitable material.

Connection between Drains and Vertical Pipes.—This has some bearing on the selection of material for drains, as there are obvious advantages in having continuity. Soil and waste pipes are never (except for chemical wastes or as a form of jerry building) made of stoneware or fireclay. They are almost invariably made of iron or lead. The connection between a metal pipe and a stoneware or fireclay drain is invariably a weak point; the joint is usually made with cement mortar, and this is less likely to remain sound than the same kind of joint connecting two similar materials. It is probable that the expansion caused by hot water may have an effect in destroying the slight adhesion between the various materials, and thus causing leakage; in any case the difficulty in getting a permanently secure joint between a stoneware or fireclay drain and a lead or iron soil or waste pipe is a further argument against the use of such drains. When both drain and vertical pipe are of iron, the joints throughout are made of lead, and are much more reliable. If one is of iron and the other of lead, the "brass ferrule" (see p. 101) makes an effective and reliable connection.

CHAPTER V

THE SIZE OF DRAINS

THE size of drains depends not only on the volume of liquid with which they have to deal, but also on the solid matters which may by intention or accident enter the system. The latter consideration fixes a minimum size, however small the amount of sewage which has to be carried. It is now universally agreed that the smallest size which will fulfil the required purpose is the best; unnecessary size is not only needlessly expensive, but it involves less satisfactory cleansing, and gives greater room for the gathering of foul air.

Minimum Size.—The minimum diameter for any drain conveying discharges from closets is generally taken as 4 inches. This has proved to be the smallest size which can be used with reasonable freedom from accidental obstruction. For short branches from basins, sinks, and the like, 3-inch pipes are often used, but not for main drains. It should be clearly understood, however, that this minimum has no reference to the carrying capacity of the pipe for liquid, and one 4-inch pipe may quite well take the discharge from several converging pipes, each of that size. It frequently happens in the case of a cottage or villa that nothing bigger than 4 inches is required. Even for a building of considerable size this would be sufficient if the drainage were strictly on the "separate" system, that is, if the rain-water were carried off by another set of drains. A 4-inch pipe, laid at any ordinary gradient, would take the sewage at the rate of 30 gallons per head per day from a population of several thousands; and though no one would act on this in practice, it is evident that for houses of moderate size it is quite unnecessary to make any calculations based on the actual quantity of sewage; any size so arrived at

is sure to be less than that dictated by experience. This will usually apply to cottage or villa property even when rain-water is admitted.

Rainfall.—In larger houses, however, the rain is the main factor in determining the size of the drains, the actual sewage being small in comparison with the possible rainfall. The proportion varies with locality, but not so much as might be expected. It is not the annual or the daily rainfall which must be considered, but the short and heavy downpour due to a thunderstorm, and this may be very intense even when the annual rainfall is low. Take, for example, a house containing ten inhabitants, with an area of roof and court of 1,500 square feet—which is not large for such a house. If the water supply is at the rate of 30 gallons per head, the total amount of actual sewage per day will be 300 gallons. A rainfall of 1 inch on the assumed area will give about 780 gallons, and in many parts of the country an inch in twenty-four hours is fairly frequent. Even on the basis of twenty-four hours, therefore, the rainfall might easily be double the sewage flow. But shorter periods give much greater intensity of rainfall. One record (Glasgow Observatory) showed eight-tenths of an inch in ten minutes, and if this had fallen on the supposed house, the rainfall in ten minutes would have been double the sewage flow for twenty-four hours. In dealing with a building which covers a considerable area, it is clear that this question of rainfall is of extreme importance.

A common rule is to allow for an inch per hour on all surfaces such as roofs and paved courts, and to add a further allowance for any garden ground or the like from which water will reach the drains more slowly—say half an inch per hour on such ground. But a rule like this is scarcely complete. The individual circumstances vary very much; in some cases even a very temporary failure of the drains to remove water promptly might have serious consequences, in others it might mean only a slight inconvenience. In the latter case, 1 inch per hour would be perfectly reasonable, while in the former it might be wise to provide for three times that amount, although

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the need for it might only occur once in a number of years. In most cases garden ground might be neglected, as unless it was of such steepness and so situated that the rainfall reached the drain by direct surface flow, the water which had percolated through the ground would reach the drain after the direct fall had passed off.

Tropical Rainfall.—Nothing which is said about rainfall has any reference to tropical countries, where the intensity of the fall may greatly exceed the figures given above.

Velocity of Flow.—In calculating the carrying capacity of a drain, the sectional area and the velocity have to be ascertained. The latter depends on the gradient and the "hydraulic radius" (sometimes called "hydraulic mean depth"), which is the sectional area divided by the "wetted perimeter." When the object is, as at present, to ascertain the maximum carrying capacity, the only condition which need be considered is that of the pipe running full. In that case the area of water A equals the area of the pipe, and the wetted perimeter P equals the circumference of the pipe. Hence the hydraulic radius $(R) = \frac{A}{P} = \frac{\pi r^2}{2 \pi r} = \frac{r}{2}$, that is, the hydraulic radius is half the actual radius of the pipe. Thus in a 4-inch pipe the actual radius is 2 inches and the hydraulic radius is 1 inch, or (the foot being the usual unit) one-twelfth of a foot.

The velocity is calculated from the formula $V = C\sqrt{RS}$, where R is the hydraulic radius as above, in feet, and S the gradient or slope, expressed as a fraction, (the tangent of the angle which the line of the pipe makes with the horizontal). V is the velocity in feet per second. C is a figure which has to be filled in either from direct experience or from calculation based on experimental data. For a long time it was regarded as a constant quantity, and its value was taken as being about 100. The roughness of the internal surface of the pipe was ignored, because it was assumed that the liquid itself formed a lubricant, which covered all the

roughness with a smooth film on which the remainder of the liquid could slide. The researches of various experimenters showed the fallacy of this idea, and it is now realised that the skin of the channel has an important influence on the velocity of the flow, and that the hydraulic radius and gradient, especially the former, have an influence on the velocity beyond that due to their square root.

The formula which is regarded as being most generally applicable is that known as Kutter's. The value of C is got by a calculation,* in which great weight is given to what is called the "coefficient of roughness." This coefficient depends on the material, and in various classes of pipe it may vary from ·011 to ·015, but should not exceed ·013 in any pipe which is reasonably clean. Most of the recently published tables of velocity and discharge of sewers are based on Kutter's formula with this coefficient, but for pipes of the character which we are meantime considering the coefficient is needlessly high—that is, the error is on the safe side. Further, it is generally agreed that with small pipes the flow is greater than Kutter's formula would indicate, and as we are dealing with small pipes the margin of safety is still further increased. Where any precise figures are required (bearing in mind that real precision is out of the question in such an inquiry) the calculation should be made from the actual data of each case, but for ordinary pipes and ordinary gradients it would probably be fairly accurate to take $C = 62$ for a 4-inch pipe and $= 70$ for a 6-inch pipe, so that in the 4-inch pipe $V = 62\ \sqrt{RS}$, and in the 6-inch pipe $V = 70\sqrt{RS}$. With the smoothest pipes in good condition, the velocity would probably be 25 or 30 per cent. beyond what these figures would give.

$$* \quad C = \left\{ \frac{41{\cdot}6 + \frac{1{\cdot}811}{n} + \frac{{\cdot}00281}{S}}{1 + \left[\left(41{\cdot}6 + \frac{{\cdot}00281}{S}\right) \times \frac{n}{\sqrt{R}}\right]} \right\}$$

n being the co-efficient of roughness, S the gradient, and R the hydraulic radius. See "The Flow of Water in Rivers and Other Channels," by Ganguillet and Kutter (Macmillan & Co.).

Discharging Capacity.—The velocity thus obtained is in feet per second, and the discharge in cube feet per second is obtained by multiplying this by the area, also in feet. A further multiplication by $6\frac{1}{4}$ gives (approximately) the discharge in gallons per second.*

Having in this way ascertained the size of pipe which would be necessary to deal with the rain-water, the question next arises whether a combined or separate system is best. It is seldom desirable to have a sewage drain from an ordinary dwelling larger than 6 inches, and when the admission of rain-water would make a larger pipe necessary, it is as a rule better to make at least a partial separation. By this means the sewage drains are kept small and are thus more easily kept clean, while the rain-water drains are not polluted by sewage at all. In such a case the latter may be made of material less costly than that which is used for the sewage drains.

In the case of very large buildings and institutions it may be necessary, even when rain-water is excluded, to calculate the carrying capacity of the pipes, and a very liberal estimate of the flow must be made. The ordinary rule as to sewers—that the pipes should be able to take off all the sewage at double the average rate—is not applicable. When no provision is made for rain-water it would be well to allow for the maximum rate of sewage flow being five or six times the average. The class of institution must be taken into account; in some it is necessary to avoid to a great extent the smallest size of pipes.† Possible extensions must be kept in view; and the separation is not always complete, and any rain-water which is admitted (or which might in the future be admitted) must be fully allowed for.

There is one warning which is most important. However safe it may be to calculate the *maximum discharging power* in the manner described, the *velocity* thus calculated is entirely misleading when applied to the ordinary flow of sewage when the pipe is far from being filled. This will be more fully considered in the next chapter.

* See Appendix, note B.

† For example, in lunatic asylums where patients put all sorts of material into the closets. See p. 197.

CHAPTER VI

THE GRADIENT OF DRAINS

Velocity Required to Prevent Deposit.—If the gradient had to be considered merely with reference to the maximum discharging power, as in the preceding chapter—in other words, if sewage were a simple liquid—there would be little difficulty in designing drainage. However flat the gradient, and however low the consequent velocity, the required discharging power could be got by making the pipe sufficiently big. But as sewage contains solid matters, which would at once settle down and remain stagnant if the water flowed too slowly, a certain minimum velocity must be maintained; and as this is produced entirely by the gradient, it follows that a drain must be laid at a sufficient gradient to ensure this minimum velocity. Failing this it becomes coated with deposit and may gradually choke up.

Factors which Govern Velocity.—The velocity of flow depends, as has been seen, largely on two factors—the gradient and the hydraulic radius. The former is fixed once for all when a pipe is laid; the *maximum* value of the latter is fixed by the diameter of the pipe, but its *minimum* value is quite a different matter. With a circular pipe running full the hydraulic radius (the sectional area of the liquid divided by the wetted perimeter) is equal to half the actual radius. The same is true if the pipe is running half full, while if the flow is anything between full and half full the hydraulic radius is somewhat greater—the empty part of the pipe diminishing the wetted perimeter more in proportion than it diminishes the sectional area of the liquid. If on the other hand the pipe is *less* than half full, it follows that the area loses more than does the perimeter, and hence the hydraulic radius is less than half the actual radius. If the

depth is very slight, the hydraulic radius becomes trifling and the velocity therefore very small. While it is easy to calculate with reasonable accuracy the maximum carrying capacity of a drain, the ordinary condition of use is that a drain seldom runs to anything like its maximum capacity; and, therefore, the value of the hydraulic radius is very uncertain and much smaller than at first sight appears.

Even in a large sewer the flow is subject to great fluctuation, but owing to the doctrine of averages the larger the sewer the less extreme are the variations. In a house drain the conditions are at their worst. There are periods of no flow whatever, varied by occasional rushes; in wet weather there may be fairly long periods of quarter or half full; and at long intervals a thunder-shower may give a flow approaching the utmost capacity. The flow in the branches is even more irregular than in the main drain. The difficulty of calculating the velocity, which exists even in the case of large sewers, is enormously greater in the case of drains.

Rules for Calculating Gradient.—So much indeed is this so that the gradient of drains is usually decided by somewhat rough-and-ready methods. A well-known rule is to multiply the diameter of the pipe in inches by 10, when 1 upon the product is said to be the proper gradient. The result is fairly satisfactory: a gradient of 1 in 40 for a 4-inch pipe, 1 in 50 for a 5-inch pipe, and 1 in 60 for a 6-inch pipe are found in practice to work very well. Under the old methods of calculation it appeared to have a strict scientific basis and to give an equal velocity whatever the size of pipe. In tables calculated on the old system we find that the velocity (half-full or full) is 4·65 feet per second for any size of pipe if the gradient is in the above proportion. It is usually assumed that the minimum velocity which should be allowed for small pipes is 3 feet per second, and the difference between this and the supposed velocity of 4·65 was taken to cover the loss due to the fluctuations of flow.

But when the more recent formulæ (see p. 37) are applied to such calculations, the resulting figures are materially

different. Even with gradients proportioned as above, the velocity varies with the size of the pipe; and for pipes of the size commonly used in house drainage, it is considerably less than the figure just given. Taking Kutter's formula with a roughness coefficient of ·013, the velocity of flow in a 4-inch pipe at 1 in 40 would only be 2·87 feet per second, in a 5-inch pipe at 1 in 50 it would be 3·08 feet per second, and in a 6-inch pipe at 1 in 60 it would be 3·26 feet per second. Not until a 24-inch pipe with a gradient of 1 in 240 was used would the velocity reach 4·65.* To get this velocity in a 4-inch pipe a fall of 1 in 15 would be needed, with the roughness coefficient mentioned; or alternatively, if the gradient could only be 1 in 40, the roughness would need to be reduced to 0·09—equal to that of glass. All these figures are on the assumption that the pipe is not less than half full.

From these figures it would appear that if a gradient of 1 in 40 is right for a 4-inch pipe, then 1 in 56 for a 5-inch pipe, and 1 in 77 for a 6-inch pipe, should be equally satisfactory. It is, however, probable that the formula of Kutter scarcely does full justice to the smaller pipes, and that the actual facts would be somewhere between the result obtained and the rule of multiplying by 10, and those obtained by Kutter's formula. But in view of the variations of flow to which reference has already been made, and which must now be more fully considered, the ordinary velocity may be very different from that calculated by any formula.

Variation of Water Supply.—The flow in a house drain is from the very nature of its use likely to be often very slight, and it is sure to be very irregular. But a further cause of difficulty has still to be mentioned. The water supply varies very considerably in different districts, and two houses might be to all appearance similar and call for very different treatment as regards drainage. One may be supplied with water from the mains of a company whose regulations are niggardly; the closet cisterns small, the bath equipment trifling or

* These velocities are taken to two decimal places merely for the purpose of comparison. Their actual precision is far short of this.

absent, and no hot water installation. The other may be supplied by a corporation with advanced ideas on the subject of sanitation, and may have all the modern conveniences which lead to water being freely used.

In the one the water consumed may be at the rate of less than 20 gallons per head per day; in the other it may be 40 or 50. Naturally a drain which would work well under the latter conditions might be very troublesome under the former. A 4-inch drain at a gradient of 1 in 40 would need no special flushing arrangements in the one case, but they would be very desirable in the other.

The (theoretical) velocity of flow in a pipe of given size running quarter-full, one-third full, and so on, can readily be calculated. The required data are, however, so uncertain and so variable that such calculations are of little value—unless as mathematical exercises.

Depth of Flow.—The self-cleansing character of a drain does not depend merely on the velocity of liquid flow. The constituents of sewage are in their early stages of considerable size, and their specific gravity differs little from that of water. If they are carried in a stream of water whose depth is such as practically to submerge them, they move as part of the stream, but if the depth is insufficient to do this they are only partially waterborne, and their weight on the invert produces considerable friction. This is a further reason for having a sufficient stream of water, and for confining it in a narrow channel.

The velocity of flow does not depend on what the hydraulic radius might be, or ought to be, but on what it actually is. It is of no use to put in a big drain so as to get a big hydraulic radius, unless provision is made to supply it with an appropriate quantity of liquid. This was at one time a very common blunder. "The bigger the drain the less fall it needs" was a half-truth well known among builders, and wherever fall was scarce it was acted upon without hesitation. Hence the common use of 9-inch pipes, with an occasional 12-inch pipe by way of variety, in draining houses of very modest size; the too honest builder used the more expensive pipe in all

innocence, with the result that the sewage was only enough to form a film on the bottom, and extremely dirty drains were the rule.

It is clear from the above that no precise figures can be given as to what is a satisfactory gradient. The best that can be done is to indicate generally the lines on which satisfactory work may be carried out, modifying the figures derived from calculation by the result of practical experience. Generally speaking, therefore, it may be said that when the supply of water is liberal—say 35 gallons per head or over—a gradient of 1 in 40, 52, and 70 for 4-inch, 5-inch, and 6-inch pipes respectively, should produce a self-cleansing drain. When the supply of water is much less, it would be well to say 1 in 30, 42, and 60. For drains which are flatter than these, special flushing arrangements are desirable. Some drains whose conditions are exceptional, such as those which convey greasy water, must be specially considered (p. 82). The rain-water when it comes is a useful agent in scouring the drains, but it is too irregular to be taken into account. Drains should be self-cleansing without it.

"**Discharge Gradient.**"—It has been suggested that the gradient should be calculated not on the fall of the drain alone, but from the closet basin or even from the flushing cistern to the drain outlet. The gradient so calculated has been called the "discharge gradient." To a certain extent this is reasonable. If sewage matters are delivered into the drain with a high velocity, due to their fall down a soil pipe, there is no reason why this velocity of entry should not be taken into account. Indeed, were it not for this velocity, many short branches would give great trouble. But to apply the principle generally is unsound. It is commonly accepted that the friction of fluid in a channel is approximately proportional to the square of the velocity; if, therefore, the sewage enters a drain, after a fall down a soil pipe, with a velocity of, say, 40 feet per second, it will in a given time travel ten times the distance that it would at 4 feet per second, but it will encounter 100 times the resistance, to say nothing of the violent splashing

which takes place. The velocity of entry is soon dissipated, and the velocity due to the gradient takes its place. The so-called "discharge gradient" is simply the "hydraulic gradient" of water engineers, and the suggested method of calculation would be perfectly sound were the pipe running full and under pressure. But in such cases the water has to move forward as one mass, its velocity at any point being due not to the local but to the general gradient. At no part is it allowed to run free. If the size of pipe is the same, it goes up hill at the same rate that it comes down, and engineers know that if at any place it has to travel at a quicker rate—say on account of a smaller channel—the effect of this on the flow is very marked.

Suppose water is to pass from A to B, through one or other of the pipes shown in diagram (vertical section) in Fig. 12.

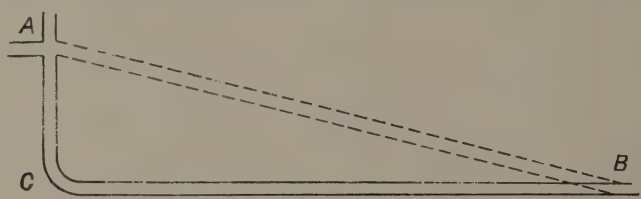

Fig. 12.—"Discharge Gradient."

If the flow is continuous, and the quantity is enough to keep the pipe constantly full, there will be little difference in the velocity of flow, whether it goes direct as shown by the dotted lines, or by way of C as shown by the full lines. The bend, and the slightly greater length, would tell very slightly against the indirect route. Take the fall (AC) as 16 feet, and the distance (CB) as 96 feet. The general gradient is 1 in 6, and the velocity of flow in a 4-inch pipe would be 7 or 8 feet per second. As the pipe is full this velocity must be the same from one end to the other. But if instead of this steady flow the water comes in rushes of 2 or 3 gallons at a time, the case is entirely different. Along the dotted course these bodies of water would pass down with much the same velocity as before. If they entered with a greater, friction would gradually reduce it; if with a less, the gradient would gradually increase it. But if these bodies of water went by the other route, they

would first fall freely to C, acquiring a velocity of about 32 feet per second, and at the bend and for a certain distance thereafter they would encounter excessive frictional resistance due to that high velocity, and as the fall has been exhausted, there is nothing to maintain their progress after the momentum due to the first drop has been spent, and their velocity must become less and less. The subsequent action depends on the duration of the rush. If it is sufficiently long-continued, the water may head up in the vertical pipe, and thus push on that in front by its pressure. Otherwise stagnation and deposit will result.

It is therefore unsafe to take any account of velocity due to fall at some other part of the system, except for a very short distance. The usual method of increasing velocity is by "flushing," which will be considered in the next chapter.

Bends.—All that has been said regarding gradient and velocity of flow is on the assumption that the pipes are straight. When liquid has to flow round a bend, an additional head is required. This may be of considerable practical importance when bends are very numerous or when velocities are high, but within the ordinary limits of bends and of velocities which are experienced in drainage work, the effect is not of practical importance. If the velocity is more than 3 or 4 feet per second, then obviously the fall is ample, and the retardation due to bends is rather an advantage than otherwise. Within the limit of these velocities it will not be found that a complete quarter bend uses so much as a quarter of an inch of head, and as it is very seldom that so many as four of these bends will occur in the length of a drain, it may usually be assumed that not more than 1 inch of the available fall is absorbed by the resistance of bends.

CHAPTER VII

DRAIN FLUSHING

The velocity of flow in drains has been considered under the condition first of maximum discharge, and next of ordinary use. When the latter is not such as to give a satisfactory flow, the operation of "flushing" may be undertaken. This is carried out by an apparatus which converts a small continuous stream into an intermittent discharge of considerable volume; and it requires (1) a storage tank, and (2) a discharging arrangement. The latter almost invariably requires to act automatically, coming into action whenever the tank is full.

Object of Flushing.—Stated crudely, the object of flushing is to wash out the drain by a heavy rush of water. More scientifically, the object is to charge the drain with water in such a way that the greatest velocity of flow will be obtained, and (usually) with the least expenditure of water. It is when water must be economised that the need for flushing is greatest; where water may be used freely, it is generally better to use it by means of larger closet cisterns than by means of special flushing tanks. Flushing tanks should not be regarded as a normal necessity, but as an abnormal arrangement to meet special conditions.

Theory of Flushing.—When a pipe runs either full or half full, as has already been explained, the hydraulic radius is half the actual radius; when it is less than half full, the hydraulic radius is less; when it is between full and half full the hydraulic radius is more. The maximum value of the hydraulic radius is when the depth of flow is about four-fifths of the diameter of the pipe. Under these circumstances, the hydraulic radius, instead of 0·5 of the radius, is fully 0·6, so

that in the case of a 4-inch pipe the hydraulic radius would be almost $1\frac{1}{4}$ inches, or practically the same as in a 5-inch pipe half full. If, therefore, water can be provided in sufficient quantity, the velocity of flow in a given pipe will not only be greater than that due to its ordinary and irregular use, but greater even than the velocity usually given in published tables, which are mostly calculated from the assumption that the pipe is half full or full. In addition to this increased velocity any solid matters will be fully submerged, and will therefore not cause obstruction by their weight resting on the invert.

Limitation of Effect.—It is obviously impossible to produce this state of affairs permanently; it is probably not possible to fully reach it even temporarily. It represents the utmost that flushing (apart from the velocity of entry) can do. The pipe which is flushed in a theoretically perfect fashion is running for the time being under conditions which make it about equal to a pipe of 25 per cent. greater diameter running full or half full, and this indicates at once the limit of what is gained by the operation.

Gradients for Flushing.—Assuming, as is commonly done, that the velocity of flow should never be less than 3 feet per second, the flattest gradient which would give this velocity in a 4-inch pipe running four-fifths full would be about 1 in 53, in a 5-inch pipe 1 in 75, and in a 6-inch pipe 1 in 100, the calculation being made from Kutter's formula with a roughness coefficient of ·013. If in addition to taking perfect flushing conditions we assumed also an extremely smooth pipe—say with a roughness co-efficient of ·010—then the gradient in each case might be about halved.

This would be going much further than safety would warrant. Three feet per second is too small a velocity for a flush in such pipes; the perfect flush condition is not possible in practice; and pipes are often rougher than would be required for that coefficient. Allowing for the fact that Kutter's formula is rather too hard on the smaller pipes, it would probably be

safe to say that ordinary flushing should not be held to justify drains flatter than 1 in 75, 90, and 120 for pipes of 4-inch, 5-inch, and 6-inch diameter respectively. By ordinary flushing is meant the arrangement whereby the velocity of flow is due altogether to the gradient of the drain, apart from velocity of entry; and where the water is supplied in such quantity that for a short time at least the pipe may be about four-fifths full.

Velocity of Entry.—These figures, like those given for gradients suitable for drains which are not specially flushed, are from their very nature only rough approximations. They are based on the work of scientific investigators, but the necessarily unknown quantities are of such importance that the scientific basis is lost in practical considerations. Under ordinary conditions they represent what may be regarded as reasonably safe. If for any reason it is necessary to lay drains at a gradient flatter than those last mentioned, the only safe way is to keep them so short that the velocity of entry of the flush will not be spent until a steeper gradient is reached. In extreme cases it might be possible to use relays—a flushing tank being provided at intervals along the course of the drain—but the cases in which this would be desirable are very few. The ordinary rule should be that drains which cannot be effectively flushed by virtue of their gradient should be avoided, unless when they are very short. Even when the gradient is such that a good flush will give for the time a sufficient velocity, it must be remembered that the flush gradually spreads out. The water may enter the pipe as a fairly compact mass, but as it travels it spreads over a greater length, the crest of the wave gets lower, and the flush becomes imperceptible. In house drainage as a rule the total length is not great, and therefore this difficulty does not emerge, but if the length of flat drain exceeds 50 or 60 yards it should not be ignored. The value of flushing may very readily be overestimated.

Flushing Water.—In the foregoing it has been assumed that clean water would be used for flushing. This should always

be the case. Attempts have been made to collect the water discharged from sinks and tubs, to retain it in tanks, and to discharge it automatically as a flush; but no one who has had occasion to examine any such arrangement after it has been at work for a while is likely to advise the construction of another. The liquid soon becomes putrid, and is most offensive. There is less objection to the storage of rain-water, but unless the storage tank is very large no water is available at the time when it is most wanted—that is, during a long spell of dry weather. If a large store tank is provided, then the dirt which is inevitably washed into it from the roofs is almost certain to make it foul to an offensive extent. Generally speaking, flushing is only applicable when there is a private and ample supply of water, or when the supply of water is by meter. Under existing circumstances it is seldom applicable to ordinary town houses, as neither companies nor corporations as a rule will permit the use of water for this purpose, unless by meter.

It might be asked, should not companies and corporations allow the use of such tanks as part of the regular and necessary consumption of water? This would not be specially desirable. Where the supply of water is liberal there is seldom any need for special drain flushing; if, on the other hand, the supply is meagre, it would be better to press for a more liberal supply for general purposes—larger closet cisterns for example—than for a supply for the mere purpose of drain flushing. There is no other use of water which gets so little value out of it; drain flushing makes least use of it. In Glasgow, for example, where the supply for domestic purposes is at the rate of about 40 gallons per head per day, and where the standard closet cistern is three gallons, flushing tanks are almost unknown.

Flushing Syphons.—When flushing tanks are required, the object is to convert a very slow feed, running constantly, into a sudden rush discharged periodically. This is effected by allowing water to trickle into a tank which is discharged automatically when the water reaches a certain level. There are

two general types of tank, in one of which the discharge is entirely syphonic, without any moving parts, while in the other the syphon action is assisted by some mechanical movement.

Non-Mechanical Discharge.—Of non-mechanical syphons the original "shallow-trap" type devised by Mr. Rogers Field, in

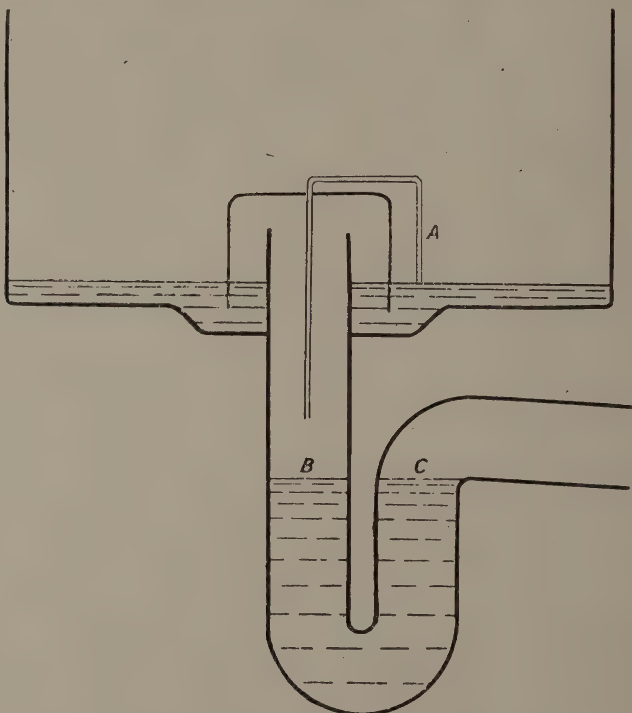

FIG. 13.—Syphon Flushing Tank beginning to Fill.

which the first dribble of water produced a diminished pressure by displacing part of the air, has been largely superseded by the "deep-trap" type, in which the air in the syphon is compressed. Its principle and action are illustrated in Figs. 13 and 14. The former shows the tank in an early stage of filling. The syphon (shown in section) is in the form of a dome surrounding a central discharge pipe, and the lower end

of this discharge pipe is bent to form a trap, so that no air can escape downward without disturbing the water in the trap. As the tank fills, the lip of the dome is first submerged, the vent pipe A being still open. The water, therefore, rises in the dome to the same level as outside, as the air in the dome is not yet imprisoned. In the figure the water has just reached the bottom of the vent pipe, and any further rise can

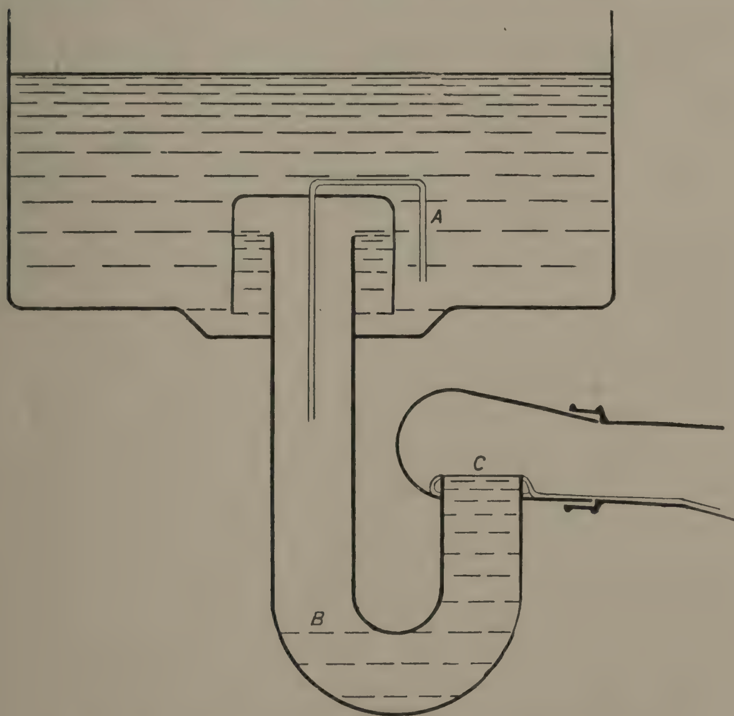

Fig. 14.—Syphon Flushing Tank on point of Discharging.

only take place by compressing the air, which no longer has any escape. The rise of water in the dome is therefore retarded, and the pressure is transferred by the confined air to the surface at B. This is gradually forced down, with the consequence that the water in this trap gradually overflows at C. Ultimately the state of affairs represented in Fig. 14 (where the same reference letters are used) is reached. The

water level at B has been so lowered that the least extra pressure will cause air to bubble through the trap to C, while the water under the dome has risen to nearly the level of the central discharge pipe. As the free level of water continues to rise, the pressure inside the dome increases, and the result is that a bubble of air passes round the bend of the trap, from B to C. This suddenly reduces the inside pressure, with the result that the water, which stands outside to a much greater height, is forced over the lip of the inside discharge pipe in considerable quantity, and the rush thus started continues until the tank is empty.

It may be noticed that at C there is a difference between the two figures. Fig. 13 represents the original form of this syphon, as first introduced by Mr. Adams, where the discharge was a round pipe throughout. Fig. 14 shows another way of shaping the outlet end, by which the water has a free fall all round, and thus gets away rather more readily than with the round pipe.

Failure of Syphons.—In such syphons there are two ways in which failure of action may occur. The syphon may fail to discharge, and the feed water, after filling the tank, may overflow smoothly through the trap without starting the syphon. With a properly constructed syphon this is unlikely. On the other hand, the syphon after discharging may fail to let go the water; the tank may be emptied down to the lower lip of the syphon dome, but the syphon itself may remain full and the water may constantly discharge. It is to prevent this that the small pipe at A in the above figures is provided; it is made of such a size that when the water in the tank has been discharged so as to leave its outer end free, it will admit air in such quantity that while it will not stop the full discharge of the syphon, it will prevent the continuance of any lowered pressure inside the dome after the flow has passed. It was found by experience that the pipe as shown, carried down outside and inside the dome, gave better results than a mere hole in the dome which at first was adopted. The small pipe fulfils its purpose very well when clean and clear water is used for

flushing, but when such syphons are used to work with water containing much suspended matter, it is not impossible that it may choke. In any case, syphons like other appliances should be occasionally inspected.

Mechanical Discharge.—There are various types of mechanically operated tanks. The most common is fed by means of an inverted ball-crane, the crane being set so as to give a dribbling feed when the ball is low, but opening fully when the ball is floated up near to the level of discharge. As the

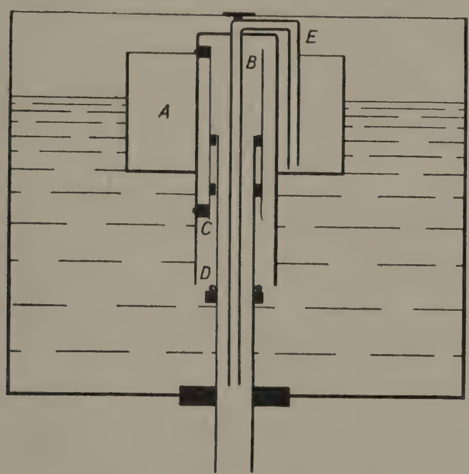

FIG. 15.—Ross's Flushing Tank.

slow feed comes into the tank the ball gradually rises, but does not affect the supply until it has reached nearly the top of its travel. Then the supply is turned on, and the strong flow readily discharges the syphon. The discharge is much more rapid than even the full feed, and the level accordingly falls, reducing the supply again to its smallest. Another type is shown in Fig. 15. This syphon (patented by Ross, Glasgow) has a cylindrical float A attached to the dome B of the syphon. As the tank fills, this float raises the dome until its rise is stopped by the lid of the tank. The figure represents its condition at this moment. As the water continues to rise in the

tank, it overflows into A, which becomes waterlogged and sinks (carrying with it the dome) until the stop C on the sliding part reaches the corresponding stop D (with a rubber ring) on the fixed upright stem. The syphon is thus entirely submerged, is at once charged, and empties the tank. The small syphon E is also submerged and charged, and by its action the cylindrical float is emptied, and is ready to rise again as the tank again fills.

Either of these arrangements is quite reliable when properly fitted, but no arrangement has yet been devised which does not need periodic inspection and occasional adjustment.

Danger of Drip Feed.—The supply of water to flushing tanks is not free from difficulty, even when it comes from an ordinary domestic main. Practically all waters have an appreciable amount of matter in suspension, and the small opening which is used to admit the water to the tank may very readily choke. It is not safe to expect that a dribbling feed will go on unchanged for it may be months at a time: the flow should occasionally be turned on full, and the most convenient way of doing this is to have a stopcock which, when closed, still allows the desired quantity to run. By occasionally opening it all accumulations are washed out, and it is then easy to bring it back to its normal condition.

The actual construction of the tank, apart from the feed and discharging arrangements, will depend on its size and position. For a large underground tank, brick in cement would probably be used, but as a rule, for the flushing of house drains a tank made of galvanized iron, and situated above ground, is more common. In the latter case the total amount of water to be discharged, and therefore the capacity of the tank, is not likely to be more than 30 to 60 gallons.

Syphon Air Pipe.—Though it is not shown, an air pipe is usually fitted to the outer side of the syphon. This introduces a danger which is often overlooked, as if the discharge is direct

into a drain or soil pipe, this air pipe is in direct communication with the drainage system, and allows gases from the drains to escape. Unless, therefore, a tank is so situated that an escape of foul air from this air pipe is unobjectionable, the discharge should not be into a drain or soil pipe direct, but through some trapped fitting. In a house, for instance, the discharge might be into a slop sink, while an outside discharge might be into a surface trap.

Size of Syphons and Tanks.—It is desirable that the flushing water should at its entry nearly fill the drain, but care is necessary lest its delivery should be too rapid. If that were so, it might come up through surface gratings and the like. Unless, therefore, it enters a part of the drain which has no connections at a low level, and which may carry water under pressure, the flush pipe and syphon should be such that they do not deliver more than the drain can take away by ordinary flow. This depends on the fall from the tank to the drain, and on the gradient of the drain. It is common in ordinary cases to use a syphon slightly less in diameter than the drain, such as 3-inch, $3\frac{1}{2}$-inch, and 4-inch respectively for 4-inch, 5-inch, and 6-inch drains, but no hard and fast rule can be laid down.

In the same way, the capacity of the tank depends on many conditions. As a rule, 30 or 40 gallons is used for a 4-inch drain, and about 60 or 80 for a 6-inch drain. The frequency of discharge is governed by the admission of water, an interval of several hours being commonly allowed between the discharges. The water supply and the disposal of sewage must both be considered in any arrangement for drain flushing.

CHAPTER VIII

TRAPS—THEIR PRINCIPLE AND EFFICACY

However clean sewers and drains may be, the air which has been in contact with their internal surfaces and their contents, and the gases which may have been generated in them, are obviously unfit for admission into the house. To prevent this, water traps are employed. It will be necessary later to consider where and to what extent these should be used, but it will be convenient first to consider their construction and efficiency.

Principle of Water Trap.—The trap consists essentially of a bend in which the liquid is retained to such an extent that the passage is entirely filled. The shape may vary indefinitely. In Fig. 16 are shown two traps, that on the left being of the type commonly used for sinks, while that on the right is an elementary form of trap for a drain. In each case the liquid enters on the right and passes off to the left; the passage of gases to the house would thus be in the contrary direction.

Gas cannot pass such a trap unless (1) it has sufficient pressure to bubble through the water; (2) it can soak through as water might soak through a cloth; or (3) the trap is not properly filled.

Resistance of Traps to Pressure.—The resistance to pressure depends on what is variously termed the "depth," "dip," "seal," "drown," and probably other names; that is, the depth from the water surface to the lowest part of the solid projection. This is indicated by the distance *a* in each of the two traps shown in Fig. 16. If pressure comes on the water-surface, this surface is pressed down until it

reaches the bottom of the projection, as shown in Fig. 17, and then the gas passes the projection and bubbles up on the other side. To force the trap, therefore, a pressure at least equal to that depth of water is required. It is in fact always more, sometimes considerably more, for the protection is against gas coming *upward*, and the water in the trap has thus to be forced further up the pipe. If the incoming pipe is vertical, this means that the pressure will be

FIG. 16.—Traps, not under Pressure.

practically double that required to force the actual depth of the trap, but if the incoming pipe is nearly flat the increased depth may be trifling. Fig. 17, which shows the two traps of Fig. 16 each on the point of giving way, illustrates this difference. Although the original depth in each case is the same, one has nearly twice the resisting power of the other.

FIG. 17.—The same Traps, Seal about to Give Way.

As a rule, the seal of a trap is rather under 2 inches, so that 4 inches may be taken as the maximum resisting power of a good trap under the most favourable circumstances. One pound per square inch is equivalent to fully 2 feet of water, so that such a trap will be forced by a pressure of less than one-sixth of a pound per square inch. Under less favourable conditions the resisting power may not exceed one ounce per square inch, while of course, when a trap is badly-

shaped or badly-set, it may reach the vanishing point. Nothing could more clearly show how essential it is that no pressure should be possible.

Gases Soaking Through.—Gases do soak through water in small but appreciable quantity. When this was first pointed out by the late Dr. Fergus (in a communication to the Royal Philosophical Society of Glasgow) considerable alarm was caused, but the investigations of Dr. Neil Carmichael (about 1880), which more recent experiments have fully confirmed, have shown that the gases in their passage are freed from germs, and their quantity is so small that in themselves they are perfectly negligible. If gases bubble through the trap it is a different matter, germs being then freely conveyed.

Traps not Properly Filled.—Apart from actual faults of construction, there are various ways in which this may occur.

Evaporation.—If a house is left unoccupied for a sufficient time, all the inside traps will naturally dry up. In a detached house this is of little consequence, as there is no one to be injured and the resumption of occupancy will soon fill the traps; but in the case of houses closely adjoining, or in "flats," the unoccupied house may be a danger to the neighbours. Again, some fitting in an occupied house may remain unused. Baths are in themselves very desirable, but it may be worse than useless to provide them for certain classes of the population. Useless traps may result from the combination of ignorance with extreme carefulness; not a few cases have been known where people have endeavoured to avoid the dangers supposed to attach to fixed basins in bedrooms by refraining from using them. Structural precautions can in such a case do little against the danger of evaporation. Outside traps may become dry by evaporation, if their seal is small, or if there is a long spell of dry weather.

Momentum.—If a trap is formed with an easy "outgo"

the water may be carried right over by its own momentum, leaving the trap nearly empty. If the flow stops gradually the trap will be filled by the last trickle, but if the stoppage is sudden this may not happen. The discharge from a Bramah closet (see Fig. 44) was exactly of the kind to produce this action, and the gradual disappearance of these closets has rendered this form of trap failure uncommon. It was easily prevented by using traps with sharper bends—Hellyer's Anti-D trap being a good example—but if this were carried to an extreme, as in the original D-trap, the remedy would be much worse than the original fault (see Chapter XIII.).

Syphonage.—There are two ways in which this may happen. In the one, water passing through the trap itself is in such volume as to fill the descending pipe beyond the trap, the water in the trap is drawn off by true syphon action, and (failing a gradual stoppage of the flow) the trap is left with no seal. Here also the Bramah closet was the chief cause of trouble. In the other the passage of water down a main pipe produces sufficient suction in a branch to draw the water from a trap, and as this is unaccompanied by any flow of water through the branch trap it may remain ineffective for an indefinite time. The prevention of syphonage in any form is easy and certain, and consists simply in effective ventilation of the traps (see Chapter XIX.).

Capillary Syphonage.—This results from a piece of rag or string passing partly through the trap, hanging over the out-go, and so draining the trap by capillary action. Traps with rough inner surfaces on which such things will catch are specially liable to this form of accident.

Pressure of Air.—This is the converse of syphonage, and as the pressure forces the water *upward* from the trap, and as gravitation immediately brings it back, the chance of the trap being left unsealed is not so great. But the momentum of the returning water leads to some being lost, and the seal may ultimately be destroyed. For this action, like syphonage, effective ventilation is an unfailing remedy.

The water trap is not free from faults, but on the whole is an effective safeguard. At best, however, it is a necessary evil, its efficacy depending on the retention of a part of the very substance that we wish to remove as quickly as possible, and its shape inevitably hindering the free flow that we wish to ensure. The tendency of modern practice is to reduce the number of traps to the minimum, and the question of how many traps are necessary is one of great importance. This is discussed in the succeeding chapter.

CHAPTER IX

TRAPS—THEIR NUMBER AND POSITION—"DISCONNECTION"

Classes of Traps.—The whole inner surface of the pipes which convey dirty materials must be looked on as tainted, and air which has been in contact with any part of it must not be admitted into the house. Every inlet to the pipes from the house must be guarded, and for this purpose the water trap is almost invariably used. It will be convenient to classify these traps as "Inlet Traps."

While all the pipes are tainted, some may be worse than others. It is usual to recognise three degrees, as follows :—

The sewer, which receives all the discharges from an indefinite number of houses.

The house drain and soil pipe, which carry excretal matters from the individual house.

The waste pipes, which convey dirty water, but no excretal matters.

It is assumed that the danger is greatest in the case of a sewer, as it may be the recipient of disease germs from each house in which a case of disease exists. A system of any extent is sure to be thus infected. The drain and soil pipe of the individual house are only infected if disease exists in that house; while the waste pipes being free from excretions are supposed to be safest of all. The rain pipes, which do not connect with the interior of the house, are not included.

Following on this classification, it is a natural precaution to keep air from a worse part from entering a better part. Hence another type of trap, known as the "Intercepting" or "Disconnecting" trap, is used, its function being to ensure that no gas from a dirtier or more dangerous part enters a cleaner or less dangerous one.

The necessity for inlet traps is practically unquestioned.

Where they are not used, it is either because some mechanical equivalent is substituted (which is rare), or from neglect. Intercepting or disconnecting traps are commonly used, but their value has been questioned by various competent authorities. The reasons for and against them are discussed below.

Inlet Traps.—Every surface which is exposed to contact with solid or liquid pollution must be cleaned, and it is a first principle in drainage design that every part so exposed should be either (1) part of the inside surface of the house, and thus subject to regular household cleaning; or (2) a pipe through which a cleansing flush of water runs. If any part of the system does not come under one of these headings, it is evidence of bad design. But the efficiency of household cleaning applied to an open surface (such as the inside of a sink, a bath, or a closet basin) is so much greater, or at least should be so much more certain, than the mere flow of water over an unseen surface, that the latter is much more apt to be unsavoury. The function of the inlet trap therefore is to separate between the two parts. Everything beyond the trap is necessarily inaccessible, but everything up to the trap should be within sight and within reach. In other words, the trap should be at, or close to, the point where the waste substances enter the pipes. It follows that every fitting should have its own trap, and the practice which used to be common of having a considerable stretch of pipe above the trap—so that one trap might serve for two or more fittings—is a bad one. As regards inlet traps, therefore, the rule as to number and position is simple; a trap for each fitting, and as close to it as possible. In closets it usually forms part of the fitting, and one side of it is accessible for brushing if this should be necessary. In other fittings it may be kept further away by the necessity for a grating or socket.

Intercepting or Disconnecting Traps.—These traps are at present the most debatable part of drainage design.* Under

* A Departmental Committee of the Local Government Board (England) has been engaged for some time in the investigation of this question.

the great majority of building bye-laws they are compulsory, and even where no such bye-laws are in force they are generally used. Until recently no one doubted their utility, and when the question was raised, the tendency for a time was to scoff at those who had raised it. The tendency still exists, along with a tendency on the part of some officials to hold that anything which controverts the bye-laws must be absurd, but the matter is really one of considerable importance, on which weighty arguments can be presented on both sides.

The debatable matter is somewhat complicated, as while the usual custom is to have the three classes all separated by traps, some of those who wish to change would do so by abolishing the trap between the sewer and the drain, others would abolish the traps between the drain and the waste pipe, while others would abolish both. Further, those who advocate a reduction in the number of traps do not as a rule do so unreservedly, but merely wish to abolish the compulsion which at present exists, so that in the case of high-class work greater simplicity may be allowed. The arguments have been developed in great detail, but the main principles on which they are based are simple enough, and may be stated as follows:

Main Disconnection—between Sewer and Drain.

Arguments in its favour.—1. The gases in a public sewer are more dangerous than any which can be generated in the drainage system of an individual house, as they may contain the germs of any disease which is present in any part of the town or district.

2. The main intercepting trap completely protects the house system from such dangerous contamination.

Arguments against.—1. The trap is an obstruction to the flow. It sometimes causes an actual stoppage, and it always implies a certain accumulation of sewage matter.

2. The trap checks all ventilation through the drain, and requires (1) a ventilator for the sewer on the outside, and (2) a ventilator for the drain on the inside of the trap. Each of these involves difficulty and danger.

3. Admitting that in the early days of sanitary engineering there was great value in such a trap, the improvement which has taken place in construction is such that nothing from the *house drainage system* need enter the *house*. That being so, it is immaterial what gases exist in the former.

Secondary Disconnection—between Soil Pipes and Waste Pipes.—This is usually enforced by regulations to the effect that no bath, basin, sink, etc., shall be connected to any pipe or drain conveying excretal matters, except through a ventilating trap. Sometimes the discharge is required to be over a grating.

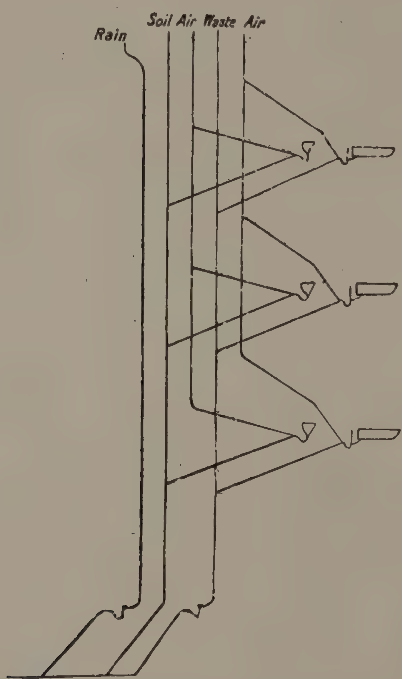

FIG. 18.—The effect of "Disconnection" in Multiplying Pipes.

The reasons for this disconnection are :—

1. The soil pipe and drain are more dangerous than the pipes which do not convey excretal matter.

2. The disconnecting trap protects the waste pipes from the more dangerous gases.

3. In the event of the traps or basins, etc., becoming ineffective in any way, the only gases which enter the house are those which may be generated in the waste pipes.

4. Hot water has an injurious action on the pipes through which it flows, owing to the consequent expansion. Soil pipes therefore should not convey it.

The reasons against are :—

1. The traps are an obstruction as in the case of the main

traps. Being more numerous they hold more; and they are usually close to the house.

2. They necessitate the provision of two pipes instead of one; or, if air pipes are taken into account, four instead of two (Fig. 18). This is not only increased cost, but a great increase in the extent of dirty pipe.

3. Waste pipes are often more foul than soil pipes (whatever the relative danger may be), due to the deposit of grease, soap, etc., and the less effective flushing.

4. The discharge of waste water over surface gratings is a very dirty proceeding.

5. This disconnection tends to a feeling of false security, and is responsible for much negligent work in connection with waste pipes.

6. Each fitting in a house, whether it connects with a waste or a soil pipe, has its own inlet trap. There is no reason why these traps should not be of equal resisting power. It is, therefore, absurd that in the case of two fittings, say a closet and a bath, in the one apartment and connected finally with the same drain, the discharges should have to travel to the drain by different pipes.

7. The argument from temperature has little force except in the case of sinks, and there even its weight is very doubtful.

8. The separation of the flow into two pipes deprives the soil pipe of the cleansing effect of the bath and other discharges.

The foregoing arguments are collected and condensed from the very numerous statements of the respective cases which the author has read and heard, and represent as fairly as possible the general views which have been stated on each side. The following is his own view of the matter:

1. **The Main Trap.**—This was a most important protection at a time when really tight drains did not exist. If the sewerage system and the drainage system were both of the highest standard of present day work and proved to be so by effective testing, it would be desirable to definitely abolish this

trap, and this might well be kept in view as an ideal by those who have to do with the planning of new districts. If, as often happens, a thoroughly well-drained house has to connect with an antiquated sewerage system, there should be no danger to the house, and the trap might be left optional.

One side issue is of great importance. If the trap were abolished, the difficulty of sewer ventilation would disappear, as the sewers would be effectively ventilated through innumerable soil pipes. When one finds that a local authority insists on the one hand that all drains must be trapped, so as to keep sewer gases out of the house *drains;* and on the other hand ventilates its sewers by gratings on the street level, from which the sewer gas has a short journey into the *houses themselves*, and a much shorter one into the lungs of the passers-by, there is a good deal of the ludicrous in the situation. The sewer gas may be so harmless that it may be safely discharged into the streets, or it may be so dangerous that it must not enter the drains, but it is not easy to see how it can be both. People live and breathe in the streets, and not in the drains, and surely what is safe in the former cannot be deadly in the latter. The soil pipe ventilators are (or should be) well away from any dangerous neighbourhood, and hence are very suitable for the discharge of any gases from the sewers.

In the same connection might be mentioned the very extraordinary view sometimes expressed, that the individual house owner has no concern with the ventilation of the public sewers. Nothing could be fairer than that each individual house, in contributing to the contents of the sewer, should at the same time contribute to its ventilation, instead of having the ventilation of 100 yards of sewer concentrated opposite one house—either on the street or in a pipe carried up the side of that house.

So soon, therefore, as we reach a standard of construction which will allow the abolition of the main trap without risk, so soon should that trap be abolished. It is already practicable to some extent, but its general abolition is not yet in sight. It is a matter of some difficulty to make a beginning,

and it is probable that a beginning would be best made by making its abolition optional where a certain high standard of construction is attained.

2. **Secondary Disconnecting Traps.**—These again were more useful in past times than they are now. When the sanitary revival began, about 1870, the pioneers were faced with the fact that bad workmanship was almost universal, that design was almost unknown, and that noxious gases escaped from pipes and traps in all directions. It was obviously a matter of many years before any far-reaching improvement could be made. Naturally and wisely they advocated the principle of various lines of defence, and one of these was the separation of soil and waste pipes. If a lavatory basin in a bedroom, as was common enough in those days, had a discharge pipe of doubtful tightness and a trap of doubtful security, it was certainly better that it should discharge into the open air than that it should connect direct with a foul drain or soil pipe. There was no certainty that even new work would be well carried out, and hence precautions against the probability of bad work were wise, even if these precautions involved certain disadvantages.

The standard of work, however, has steadily risen, and there is no longer any reason why good work should not be always attainable. The balance of advantage, which used to be wholly on the side of disconnection, has been much affected by this change, and in many cases it now inclines the other way. At present, in the opinion of the author, it stands thus:

Where a disconnecting trap can be used without any duplication of pipes—that is, where the question is merely whether a given waste pipe should or should not be trapped before it connects with the drain—the question is an open one, and the answer depends on general convenience. The advantage of the trap for inspection or testing may be sufficient to justify its use.

Where, on the other hand, soil and waste connections have to join the drain at the same place, and where these originate

in the same or similar apartments, and where, therefore, the use of a disconnecting trap means the duplication of pipes, it is difficult to criticise too strongly the regulations which insist on such a practice. The duplicated pipes are more costly, more unsightly, more unclean, and more dangerous than the single pipe would be, even if both are treated with the care that would be given to the soil pipe. If the waste pipe is dealt with in a more negligent fashion, as often happens, the evil is intensified to an indefinite extent.

It is unfortunate that most sets of building bye-laws are based on models which date from the time when good work was the exception, and that they are disfigured by requirements which under present conditions are harmful rather than useful.

It must, however, be clearly understood that the author's condemnation of the customary rules, and his opinion that they should be revised, implies that they should be revised also to insist on the best material, proper design, and effective testing. If this in the meantime is too drastic to be applied all round, the effect would be attained indirectly by retaining the present bye-laws with their complication and their comparatively low standard of work; but offering the option of a very free hand in the matter of disconnecting traps (both main and secondary) on condition that the work should be of the highest class. This would give an impetus to high-class work, and the saving in complication would usually make it cheaper to comply with the most severe restrictions as to quality.

Rain Pipes.—These are in a class by themselves. They should never be offensive, and they necessarily end in such a way that gases coming from them readily enter the house by the eaves. They should, therefore, never be used as ventilators for any soil or waste pipes, but should be kept entirely separate by means of traps (see p. 179).

General.—Apart from any addition which they may make to the safety of the system, traps within limits are a convenience for inspection and testing, and their gratings are useful

indicators of the position of the drains. On the other hand, they are not ornamental when placed among flower beds and grass verges, and their appearance is often regarded as an objection. There is no doubt that trapping has been very much overdone, and that considerable modification of the usual requirements would be an advantage in every way. But disconnection to a reasonable extent has certain advantages, and its complete abolition would be as unsatisfactory as its excessive use. Fewer traps, better work, and more severe testing, is the present direction of progress.

CHAPTER X

INTERCEPTING TRAPS AND CHAMBERS

It is unnecessary in this connection to consider the cesspool or built trap. It still has its use for disposal purposes (see p. 247), but it is not now used to prevent the passage of air or gas from one section of drain to another. Traps are invariably made in pipe form.

The Evolution of the Trap.—The elementary trap, from which the present forms have been developed, is shown in Fig, 19. There was no access for inspection or cleaning, and there was no shaft to the surface to indicate its existence. If it choked,

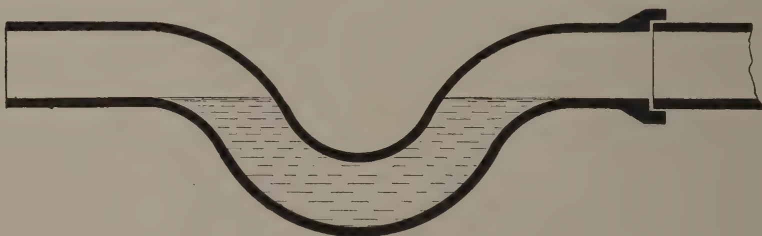

Fig. 19.—An elementary Form of Drain Trap.

it could only be reached by exploratory digging, and finally by breaking the pipe. The addition of a central eye, with a shaft carried up to the surface and ended with a close cover or lid (Fig. 20), was a natural development. While the shaft showed the position of the trap, and allowed it to be cleaned by the use of a scoop or ladle, it was itself an additional receptacle for dirt, as any light substances rose in it, and were not removed by the natural flow. There was no provision for ventilation, and the facilities for inspection were very poor.

Ventilation was often provided by carrying up another shaft from the drain immediately above the trap, as shown by the light lines on Fig. 20. This arrangement is probably still to be found, although it is now entirely out of date. The first real "ventilating trap" appears to have been the "Somerset" trap introduced by the well-known architect, Dr. Honeyman, but superseded almost immediately by the universally known "Buchan" trap (Fig. 21). The most important new feature of the latter as compared with the former, was that on the outgo side the rise was gradual and easy, so that matters heavier than water were readily washed through. It

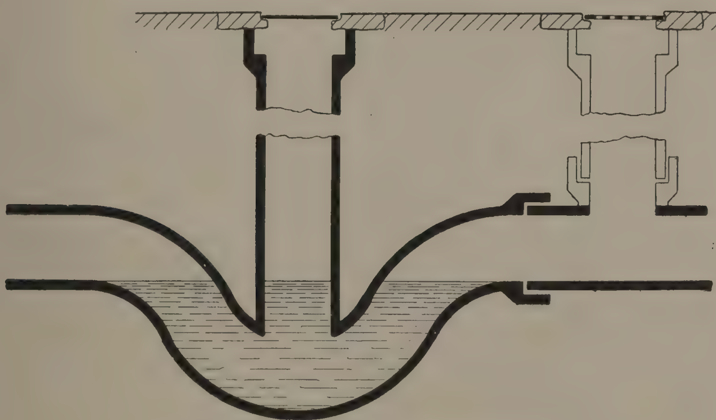

FIG. 20.—Drain Trap with Centre Eye.

had in common with it an opening directly above the water surface, which allowed ventilation, inspection, and cleaning when required. Buchan also introduced a vertical drop of about 2 inches into the trap from a square edge. This "cascade action" was of more value when first introduced than it is now, as the drains then were much bigger and the tendency of light substances to float in the trap was thus greater. To allow the air to pass freely, the top of the inlet side was bevelled. The eye shown on the outlet side was added if required for sewer ventilation or for inspection of the pipe below the trap, but it was frequently omitted.

Such a trap, with its inlet side continued by a pipe to the surface and covered by a grating, was a simple and effective form of ventilating trap. The original patents have expired long ago, and the trap is now public property. It is still made in enormous quantities in practically its original form, and it has been the basis of many modifications. It would scarcely be too much to say that almost every trap of the present day has been evolved from the Buchan.

One frequent and useful variation is to have the trap made in two pieces, so that the inlet and outlet may be at any angle

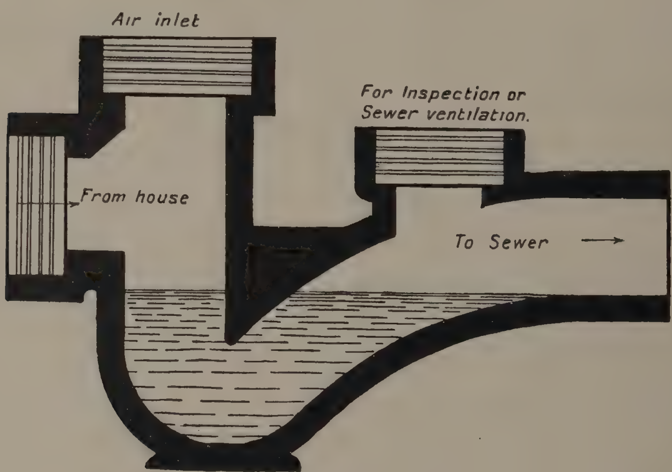

FIG. 21.—Buchan Trap.

with each other. This (along with the shaft to the surface, referred to on p. 76) is shown in Fig. 22 (slightly different also in general type), and it will be noticed that it involves a greater fall (at least in the case of iron traps, where room for staving is needed) although the joint may be brought right down into the water.

While the traps above shown, with their simple shaft to the surface of the ground, are quite effective for trapping, ventilation, inspection, and also for cleaning the traps themselves, they give no facilities for cleaning the drain above or below if that should be choked. For this, a much more elaborate

arrangement is needed, and the "intercepting chamber," or combination of trap and manhole, is used. This allows a man to get down to the drain level, and provision is made for passing rods either up or down the pipes.

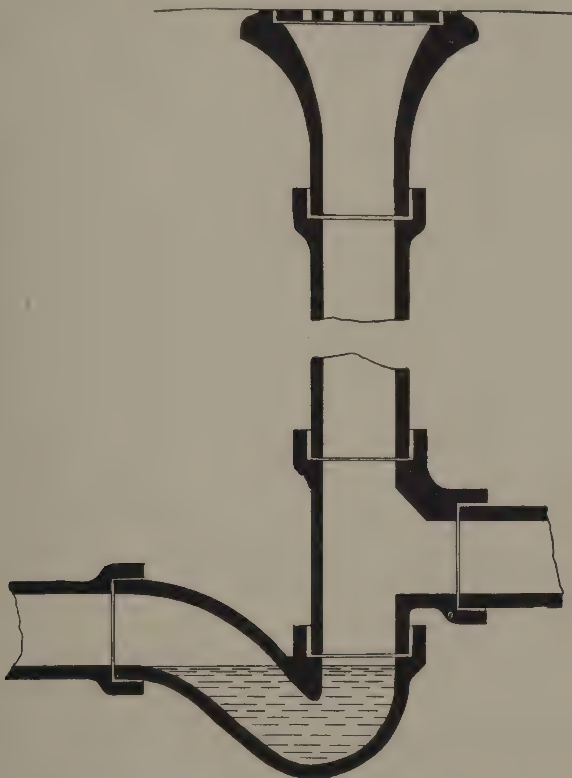

FIG. 22.—Trap in two Pieces, with Shaft and Surface Grating.

Intercepting Chamber.—In detail of construction, this is simply a manhole, and particulars will be found in Chapter XI. The combination of trap and manhole may be in either of two forms, represented in general character—the details being very variable—in Figs. 23 and 24 respectively.

The intercepting chamber shown in Fig. 23, is part of the drain, so far as its air capacity is concerned. The drain passes through it in an open channel, formed of half pipes,

and if any branch drains join at this place (one is indicated in the figure) they also run in open channels formed in the floor of the chamber. Ventilation is provided by a pipe brought from an inlet grating, and the chamber is finished at the surface by an "air-tight" cover. If the drain above the chamber is obstructed, rods can be passed up without any

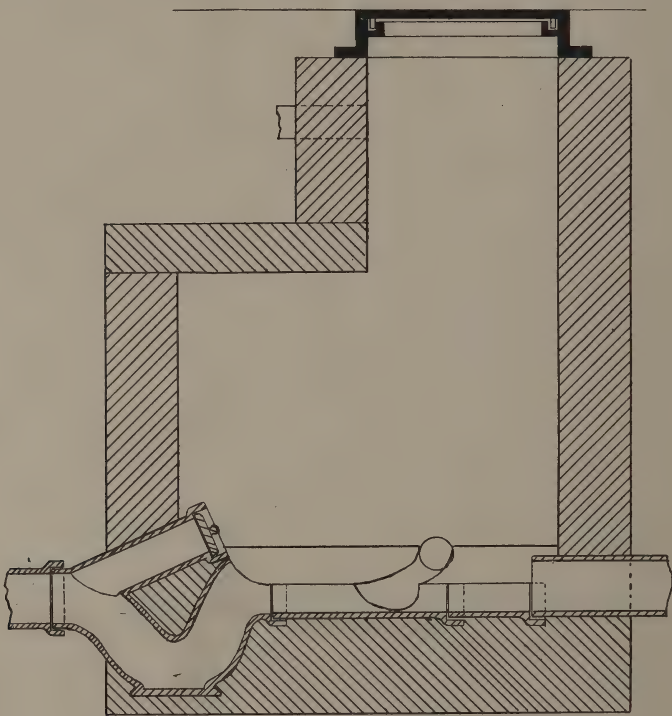

FIG. 23.—Intercepting Chamber, open Channel.

preparation other than lifting the cover at the surface: if on the other hand there is an obstruction on the lower side, the lid of the "raking arm" must be removed.

The chamber shown in Fig. 24 is not in any sense part of the drain: it merely gives access to the outside of it. If it is required to pass rods up the drain, a cover has to be removed from the pipe itself; if the rods are to pass down, a cover is removed from the raking arm. The chamber has no need of

an air-tight cover, and there is no absolute necessity for its being air-tight or water-tight. The air inlet is carried through the chamber for convenience, but it might conceivably be connected in any other way. The removal of the manhole cover is merely a preliminary to opening the drain, and does not expose any part of the drain to the outer air.

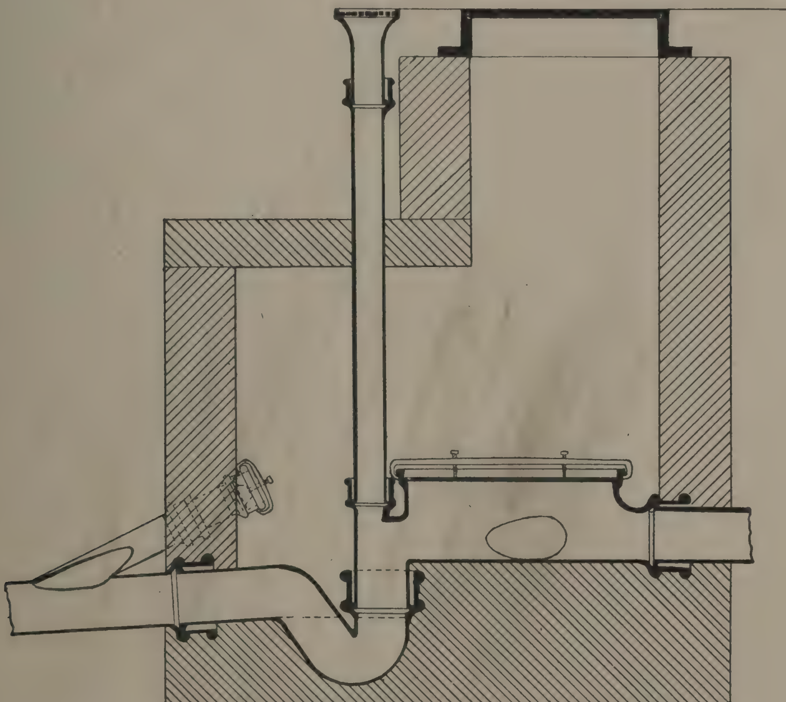

FIG. 24.—Intercepting Chamber, closed Channel.

There are objections to either type of chamber, but they are much more numerous in the case of the former. If an obstruction takes place in the trap or below it, the sewage is ponded up not only in the drain, but in the chamber as well. The built walls are more likely to leak than a pipe is, and given a certain amount of leakage, the choke might be undiscovered for a considerable time. At the best, a large accumulation takes place, and a considerable surface is fouled

by the ponded sewage; at the worst, the chamber may remain for an indefinite time as a leaking cesspool, giving no indication of danger, but polluting the soil all round. If the plug of the raking arm is to be of any service, it must be of a kind that can be removed with reasonable facility, and it may be suspected that it is not always carefully replaced. The trap is useless unless this plug is in place and air-tight.

Not the least of the arguments in favour of cast iron drainage is the fact that it naturally forbids this type of intercepting chamber, and makes it imperative to use either a simple trap such as Fig. 22, or a chamber of the type shown in Fig. 24. It would be very inconsistent to construct an air-tight drain and provide chambers or manholes in which the air-tightness depended on built walls and manhole covers.

The air inlet, either for the chamber or plain trap, may be in any convenient place, connected to the trap or chamber by an air pipe. It is not always easy to find a place where a blow *out* would be quite inoffensive, and experiments have shown that these so-called "inlets" often allow a considerable quantity of air to escape from the drain when water is rushing down. The objection to this, especially in closely built streets, is obvious, and is quite fairly used as an argument against the use of intercepting traps. One way in which the objection may be minimised is to make the inlet grating vertical, and so placed that when the wind blows toward the house it will also blow into the grating and check any outflow of air; but this is by no means a complete protection even for the house, and it is none for passers-by.

Inlet Valves.—Valves with mica flaps are used to ensure that the current can only pass in the desired direction. The motive power, however, consisting of a slight current of air, is so feeble that it is scarcely possible to have any sort of valve which will be effective without being a very serious obstruction.

Chamber or Shaft.—It is often a question whether a built chamber or a simple trap with a pipe shaft, such as is shown

in Fig. 22, should be used in some particular case. If the drain is deep, or if the trap is to be placed where the inconvenience of reaching it by digging would be serious, then a built chamber is indicated. If, on the other hand, there would be no great difficulty in digging if this became necessary, then the cost of the chamber might well be saved. A choke

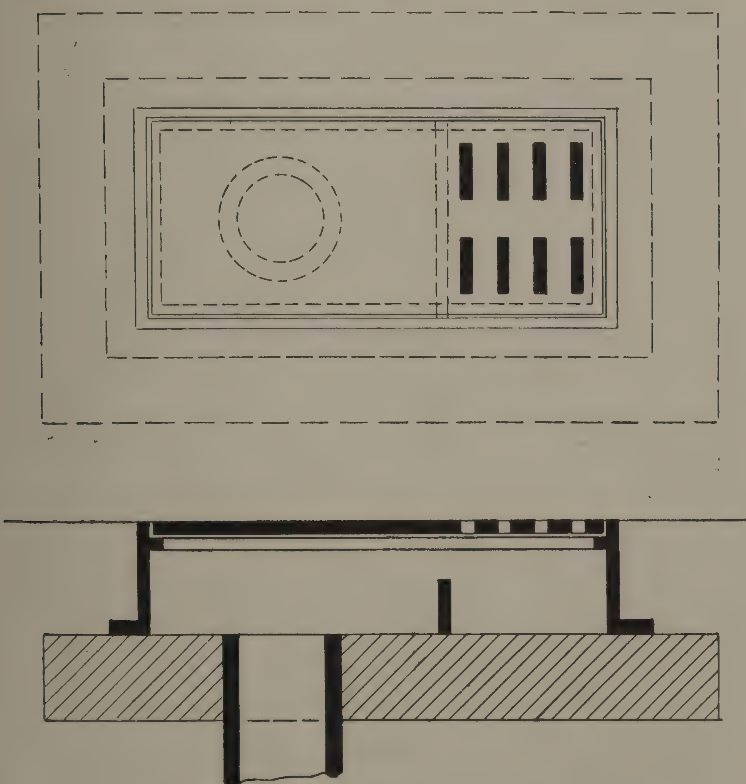

FIG. 25.—Ventilating Cover, partly unperforated.

should not be a probable contingency. It is customary in some quarters to regard the intercepting chamber as a matter of course, but many thousands of traps with pipe shafts are in use, and the percentage which gives trouble is very small, It has been suggested with some plausibility that traps with pipe shafts are less likely to choke, or at least are more likely

to clear themselves at once, than traps with built chambers: the point being that with the small shaft the water banks up rapidly in the event of a choke, and the resulting pressure may drive away the obstruction before it has become compacted. In any case, the great majority of choked traps can be cleared from the surface by the use of tools through the shaft.

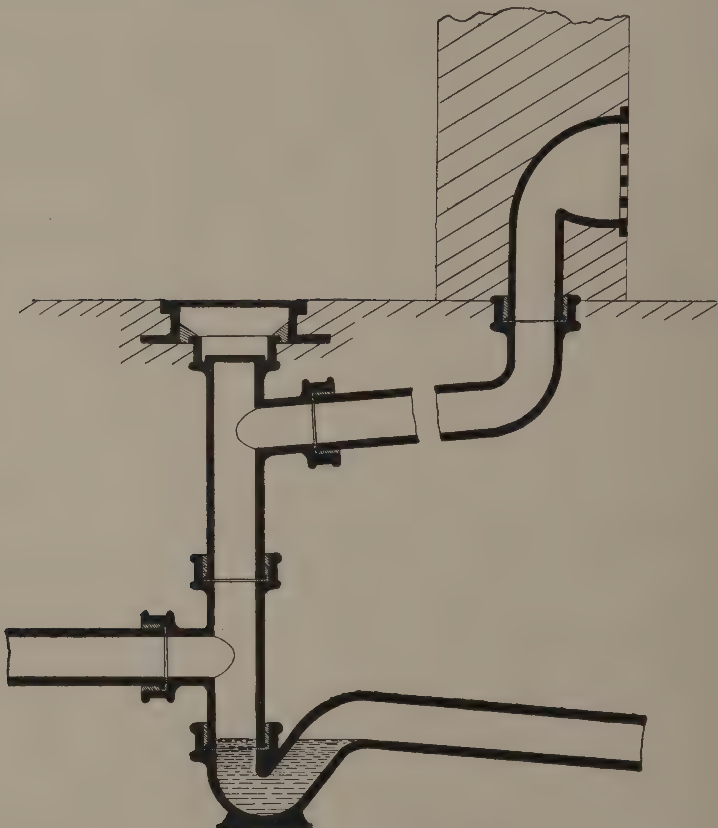

FIG. 26.—Trap, with Wall Grating.

Air Gratings.—When the air inlet is by a flat surface grating, whether a built chamber is used or not, solid matters may enter it by accident or design. For example, gravel may fall through, or children may push in sticks; and it is usually desirable to have the grating set at least to one side of the

shaft. This is conveniently done by the use of oblong gratings, such as that shown in plan and section in Fig. 25. One side only of the cover is perforated, and it is the unperforated part which is directly over the shaft. If a greater distance is required, an air pipe is carried to the required place, but care must be taken that the air pipe itself is not likely to choke. It may be desirable to have a sump under the grating, to retain any solid substances, but it should be arranged so that water will drain away. If an air pipe ends at a grating in the face of a wall, as is often convenient, it is desirable to use one of the special castings made for this purpose (Fig. 26), as this ensures the continuity of the system, which is then of iron piping right to the outside.

Traps for Waste Pipes.—These as a rule are of small or moderate depth, and do not require a built chamber. Their form will vary according to the class of liquid which passes through them, their depth, and the number of branches. Examples are given later.

FIG. 27.—"Gully" or "Barrel" Trap.

Two obsolete methods of disconnecting waste pipes should be mentioned :—

Discharge over Grating.—This used to be extremely popular, apparently from some idea that the disconnection was thus more complete and certain. The grating and its surroundings were kept wet and sloppy ; it was apt to be obstructed by substances strained out of the water, and by leaves, scraps of paper, and the like, which might be blown on to it ; and splashing over the surface was very common. Whatever benefit is got from disconnection is got equally well by bringing the waste water in

under the grating, and bye-laws which require the over-grating discharge are urgently in need of revisal.

Retentive Traps—This also was popular, the "gully" or "barrel" type of trap (Fig. 27) being used. Such traps are well suited for taking surface water from roads, walks, and other places from which inorganic refuse may be washed by the water, but they should never be used where dirty water is to pass. The self-cleansing type should always be used for that purpose.

Cistern Heads.—A further "disconnection" is sometimes carried out by discharging the waste water from baths or basins into an open "cistern head" on the waste pipe. This is quite contrary to modern views; it needlessly fouls a considerable surface, it exposes that surface to the air, and it prevents proper testing.

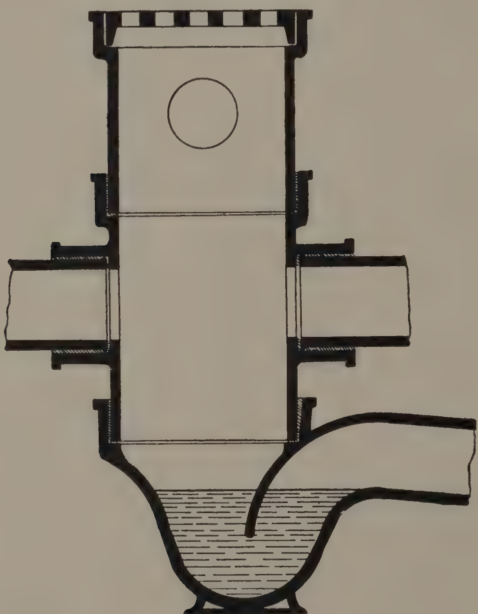

Fig. 28.—Trap with Enlarged Shaft.

Trap Shafts. —Where only one connection enters the trap (or where there are more than one, but at suitable angles for joining at the same level) and where the depth is small, the ordinary Buchan trap 3 inches or 4 inches in diameter is very suitable. The top of the shaft may have a bellmouth and grating (see Fig. 22, p. 73), but the enlargement is above the water inlet and the wetted area is thus kept small. The access

to the trap from the surface is through a small shaft, but choking is not probable.

More convenient access can be got, at the cost of an increase in the wetted surface, by the use of the arrangement shown in Fig. 28. The trap itself has an enlarged mouth, and "eke pieces" are used above it. These are usually 10 inches in diameter, and 9 or 12 inches high. Any number of branches up to four can be cast on any one of these, and if the shaft is formed by building up several of these pieces it is easy to connect branches coming at what would otherwise be awkward angles. While the branches cast on any one piece must be at the angle fixed by the casting, the successive pieces may have branches at any angle with each other. The application of this device is, of course, subject to the required fall being available.

Water-tight Shafts.—It is of the utmost importance that the trap shafts should be water-tight right up to the surface. The want of this may have serious results. Fig. 29 shows an arrangement sometimes found, the space between the top of the trap and the pavement being filled by rough building. If the trap chokes, the liquid simply rises to this part and flows away into the surrounding soil, and this may long remain undiscovered. Where it can be done, the iron pipe should be brought right up to the surface; failing that, any space should be thoroughly and strongly built up with brick in cement (see Fig. 32, p. 85). Any obstruction then causes the liquid to rise till it overflows at the surface, where it is at once seen. This precaution is even more important in the case of branch than of main traps, as the greater volume of liquid in the latter is less likely to escape unnoticed.

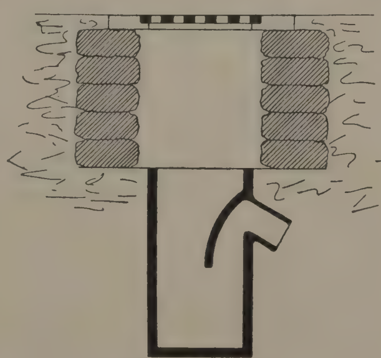

Fig. 29.—Rough Building above Trap.

Grease Traps.—The greasy water from scullery sinks is the most troublesome part of the liquid with which the drains have to deal. It is often hot when discharged, and the grease in it is liquefied by the heat. As the water cools, the grease becomes solid, and is readily deposited as a coating on the cold pipe, causing serious obstruction. To avoid this, it is common to provide a receptacle of considerable capacity, into which the hot water runs, and where it is cooled by mixing with the water already there. The grease gathers on the surface, first as a scum and ultimately as a cake; at intervals it is removed by hand and disposed of in the garden or otherwise. In theory this is simple, but it is apt to work badly in practice.

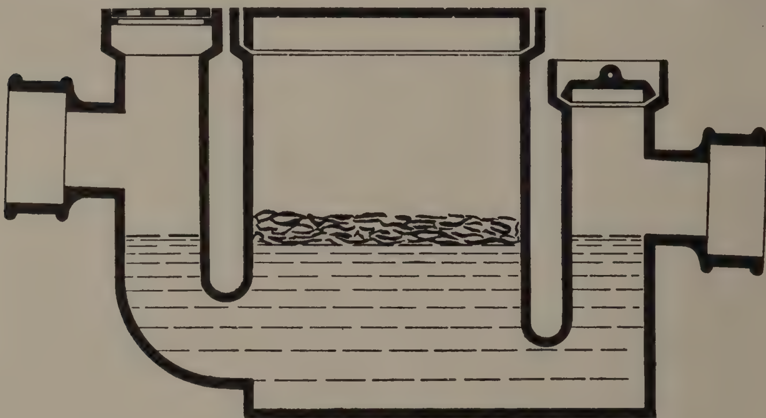

FIG. 30.—Trap to Retain Grease.

It is impracticable in a small house, as domestic servants will not remove the grease. In a larger establishment the duty is usually assigned to a gardener, and it may or may not be well done. At best, the cleaning of a large grease trap is a very offensive operation, not only to those actually concerned but to everybody in the neighbourhood. The grease is putrid before it is removed, and the smell is horrible. Many forms of grease trap have been devised, but they can at best only palliate the evil.

They follow as a rule one or other of two main lines: either the provision of means by which the grease can be removed

with the least possible inconvenience by hand, or the entire abandonment of hand removal and the direct discharge of the grease through the drain. The first is exemplified in Fig. 30, where the grease cake is encouraged to form in a compartment screened off from the main flow of liquid, and where a lifting arrangement may either remain as a permanent part of the trap or be brought to it when required. The success of this depends altogether on the attention which it receives, and the operation of cleaning is almost inevitably offensive.

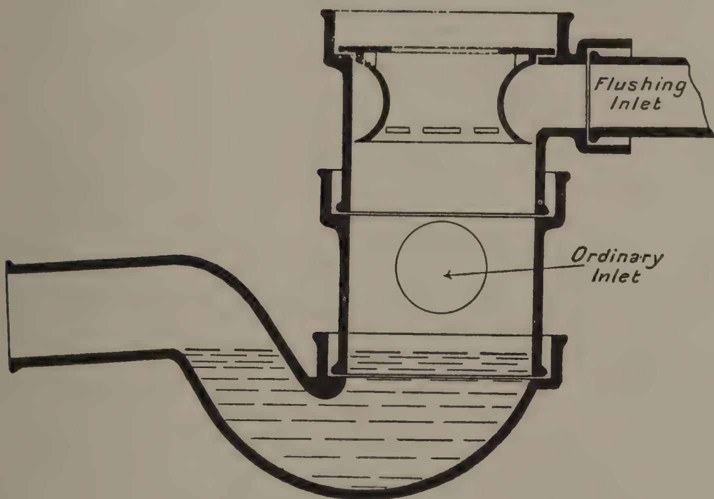

Fig. 31.—Flushing Grease Trap.

The second is usually carried out as shown in Fig. 31. The trap is not bigger than an ordinary waste trap, but in place of depending altogether on the natural flow to keep it clean, a flush of clean water is sent through it at intervals. This flush is delivered above the ordinary inlet, and is directed round the trap shaft by a flushing rim, very similar in principle to that used on the basins of closets. The water is from a special flush tank, and is, of course, clean. Such a tank, discharging 10 to 20 gallons through a pipe of such size as will give a rapid rush, has an excellent effect on the drain as well as on the trap. The size of the flush pipe should not be less than

2 inches, and it should be more if the length is great or the fall slight.

The attempt should not be made to flush out the trap by its own syphon action. The greasy liquid is specially unfitted to actuate a syphon, and constant attention is needed to keep the latter in operation. Besides, it involves the gradual filling and sudden emptying of a receptacle of considerable size, wet sides being thus left exposed, and the alternate wetting (with a foul liquid) and drying is very objectionable.

On the whole, the method of flushing out the trap and letting the grease go down the drain is generally less objectionable than any system which retains the grease. But in a drain which chiefly conveys greasy water it is desirable to make more than ordinary provision for cleaning should that be necessary. It is probable that where grease is flushed through the drain clogging will take place more readily than when it is systematically removed from a trap by hand; but the latter is not a certain safeguard, and the diminished risk of choking scarcely compensates for the recurring unpleasantness.

Disconnection of Rain Pipes.—In classifying the pipes of a house with regard to their danger or offensiveness, we have soil pipes, waste pipes, and rain pipes. When it is desired to simplify construction by combining two of the three classes, the grouping of soil and waste, or of waste and rain, has each found advocates—the latter much more frequently. It is, however, very objectionable for many reasons to treat waste pipes and rain pipes as if they formed one class. The waste pipes ought to be air-tight, and the air contained in them ought to be excluded from the house. The rain pipes, on the contrary, can scarcely be air-tight, and in any case must end in such a place that any gases which escape from them get readily under the eaves. If waste pipes are connected to rain pipes, the standard of construction which suits the latter is apt to be applied to the former. Waste pipes have much more in common with soil pipes than they have with rain pipes, and if grouping is to be done at all, the soil and waste pipes should be grouped together, the rain pipes being treated as a class by

themselves. In the case of pipes or drains conveying only rainwater, while mischief might result from actual leakage or overflow, a slight departure from absolute tightness could not be regarded as serious. In ordinary drains, it is not the water but the substances contained in it that are dangerous ; in rain-water drains the contents are not dangerous unless they escape in some quantity. So long as they are effectively trapped off from the main drains, there is no reason why they should not be constructed of stoneware or fireclay. The trap, however, should be of iron. Where there is a convenient manhole, a rain-water trap may be set in its floor, and the rain pipes

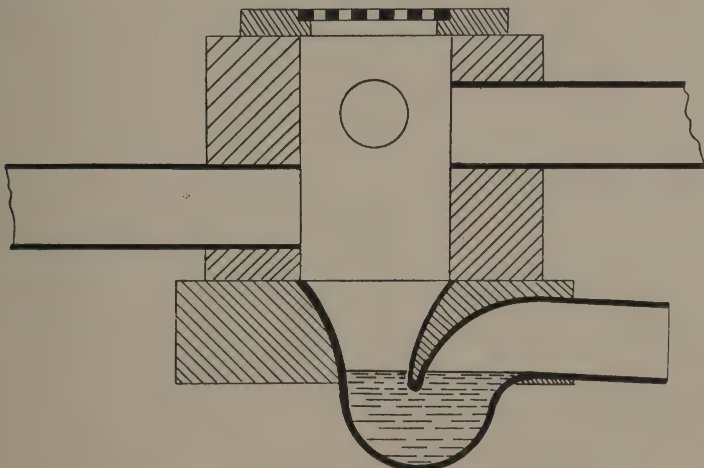

FIG. 32.—Trap for Rain Pipes.

may then discharge openly into the manhole. Such an arrangement is shown in Fig. 37, p. 92. Where no manhole is convenient, and where there are several rain-water pipes to be connected, an iron trap with a built superstructure (Fig. 32), through which the drains are built, may be used. When only one connection has to be made, any ordinary iron trap, with a larger socket on the inlet branch to take the stoneware pipe, is quite satisfactory. Where building is used, special care must be taken to have it tight up to the surface (see p. 81), and where the trap is in a manhole floor the chance of the sewage flooding back into the manhole must not be overlooked.

Parallel Drains.—The desire to separate the different kinds of drains has sometimes led to two pipes being laid side by side for long distances, carrying different classes of liquid. To a small extent this parallel system may be unavoidable, except at the cost of multiplying traps unduly; but in principle it is radically bad, and the rule should be to concentrate the flow into one channel as soon as possible. The double pipe means increased amount of dirty surface, and diminished flushing. This is dealt with more generally on p. 177, and illustrated in Fig. 82.

Connection for Subsoil Drains.—There should, if possible, be no connection (see pp. 10—12). Sometimes, however, it is

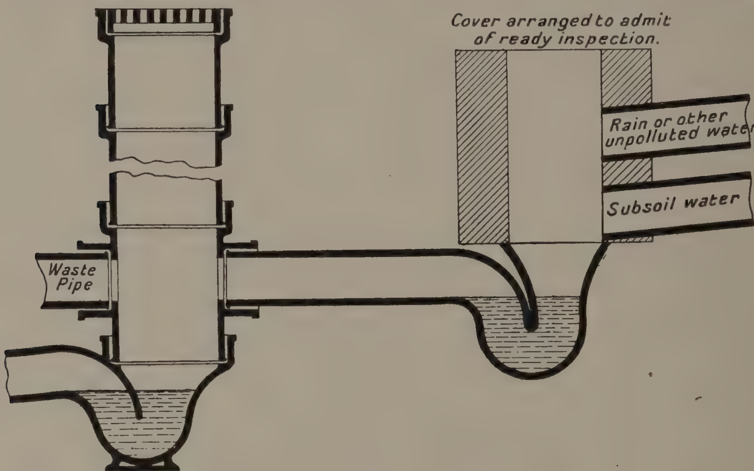

FIG. 33.—Connection for Subsoil Drain.

not possible to have the open discharge which is desirable, and the subsoil drains must then be connected to the ordinary drainage system. It is only in extreme cases that the flow in these drains is sufficiently constant to ensure that a trap will always remain sealed, and it is not therefore enough merely to trap the subsoil drain. It is usually desirable to feed the trap independently, say from a rain pipe, and to make it of such a type that evaporation will not be encouraged. Of course, if any constant stream of clean water is available, it is

to be preferred to rain water; and in buildings where water power is used for any purpose the solution of the problem is obvious. Where only rain-water is available it is well to lead the discharge from the subsoil drains through a second trap, this being connected with the waste fitting which gives the cleanest discharge. In a large establishment there is usually some form of sink from which the discharge is fairly clean—its use being to wash crystal, china, etc.; to water flowers, or the like. Such an arrangement is indicated in Fig. 33. If possible, there should be an open surface at such a level that in the event of a choke the water would escape there (and cause inconvenience) before it backed up into the drain, from which it would escape into the soil undetected.

CHAPTER XI

INSPECTION OPENINGS AND MANHOLES

The primary object of a drain—the provision of a uniform and continuous tube—is modified by certain other requirements. One of these requirements is to check the passage of gases, and is met by trapping; the other is to provide facilities for inspection or cleaning, and is met by inspection openings and manholes.

The terms "Inspection opening" and "Manhole" are often used indiscriminately to denote the whole arrangement, but each is really a separate part. The drain is buried in the ground, and in ordinary circumstances would be reached by digging: the construction of a manhole avoids this necessity and allows a man to reach the outside of the pipe. He can then obtain access to the interior of the pipes by means of the inspection opening. An illustration of this is given in Figs. 34 and 37. With a pipe which is not buried the inspection opening only is required, and in certain circumstances this may be sufficient even in the case of a buried pipe (see p. 95).

Object of these Openings.—They give facilities for examining the inside of the drain both during construction and at any subsequent time, so as to ensure straightness, regularity, and freedom from obstruction. If any obstruction should occur, they permit the introduction of rods for its removal. If in testing a defect should be detected, it may be traced to one particular section, and the area of investigation thus restricted.

The openings are a convenience and safeguard rather than a necessity. In thousands of cases they are not provided at all, and often when they are provided they are never used. But if a stoppage should occur in a drain not so equipped, the result is not only a great disturbance of the ground by digging,

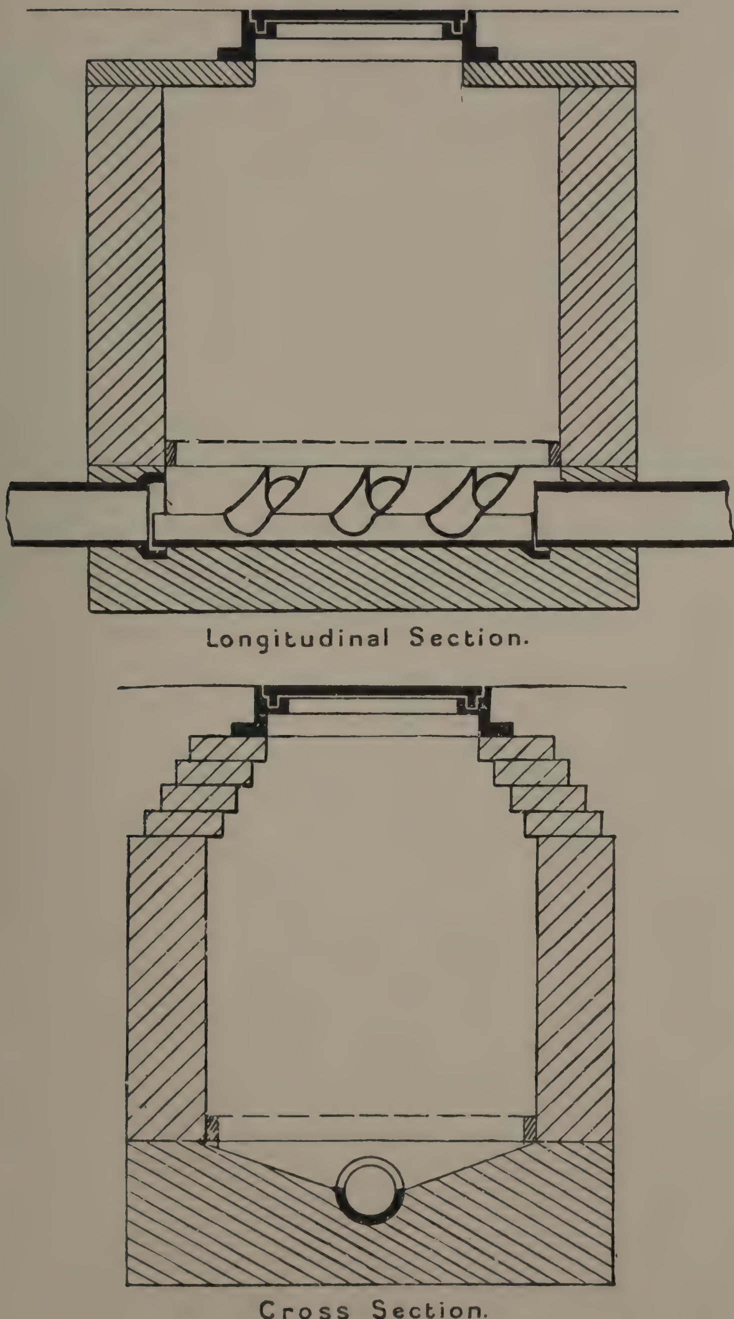

FIG. 34.—Manhole with Open Channel.

but serious and often irreparable injury to the drain by breaking into it: on the other hand, proper access allows the drain to be easily cleared. It is not part of the actual working system, but an adjunct which may be very valuable in case of emergency.

Drawbacks.—The surface covers may be unsightly or in the way: the openings themselves may be not at best very securely closed against the passage of gases, while negligence may leave them entirely unclosed: they form (in some types) a reservoir of more or less stagnant air: and they add considerably to the cost. They are therefore to be regarded as an undesirable necessity, and used as sparingly as possible.

Types.—The inspection opening may take the form of an open channel, or of a pipe with a removable lid. These correspond to the two types of intercepting chamber, described on pp. 73—75. In the former the manhole becomes part of the drain, and the barrier against the escape of gas is at the ground surface. This type is illustrated by the two sections shown in Fig. 34. It was much in favour at one time, but may now be regarded as out of date. Its chief convenience was that branches to any number and at any angles might be connected into its open channel, and the white enamelled channels, with floor and sides of the same surface—or the sides even of plate glass—presented an attractively bright appearance. The brightness might not last long, and the difficulty of making such a building air-tight was enormous. At the surface an "airtight" cover had to be provided, and in spite of all the ingenuity which was exerted in devising these, it was easy for accident or carelessness to render it useless. Sometimes a second cover was used near the bottom of the manhole, indicated by the dotted line in the figure, but even this enclosed a number of built joints, and was much inferior to the provision of a tight lid on the pipe itself.

Covered Openings.—When iron drains are used, the inspection opening is provided by a pipe with an iron door. The

door is of cast iron or of thick iron plate, and is secured by screws in some form or by locking levers. A convenient fastening is that shown in Fig. 35, where a bridle and pinching screw (more than one in the case of a large cover) are used. The bridle is of wrought iron and the screw of gun-metal, and the point of the screw forces the plate home. In Fig. 36 bolts and nuts are shown: these give a better distribution of pressure, but are from their greater number more troublesome to manipulate. They also should be of gun-metal, as with iron bolts the trouble is greatly increased by rusting. In either case the cover must be screwed down on some soft material; rubber or leather washers are sometimes used, but red lead putty and oakum is the most common packing. The complete manhole is shown in Fig. 37.

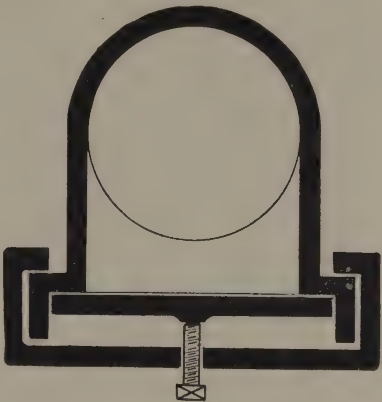

Fig. 35.—Inspection Cover with Bridle and Screw.

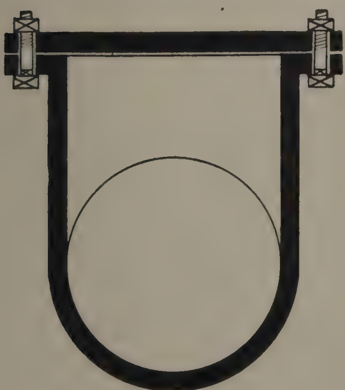

Fig. 36.—Inspection Cover with Bolts and Nuts.

It will be observed that in Fig. 35 there is a raised flange into which the cover is set. This is often convenient when air pressure is used for testing, as the shallow dish thus formed may be filled with water, which at once shows any escape. Otherwise the flat flange is equally suitable, and may be less troublesome to lift.

Stoneware and Fireclay Pipes.—It has already been said that

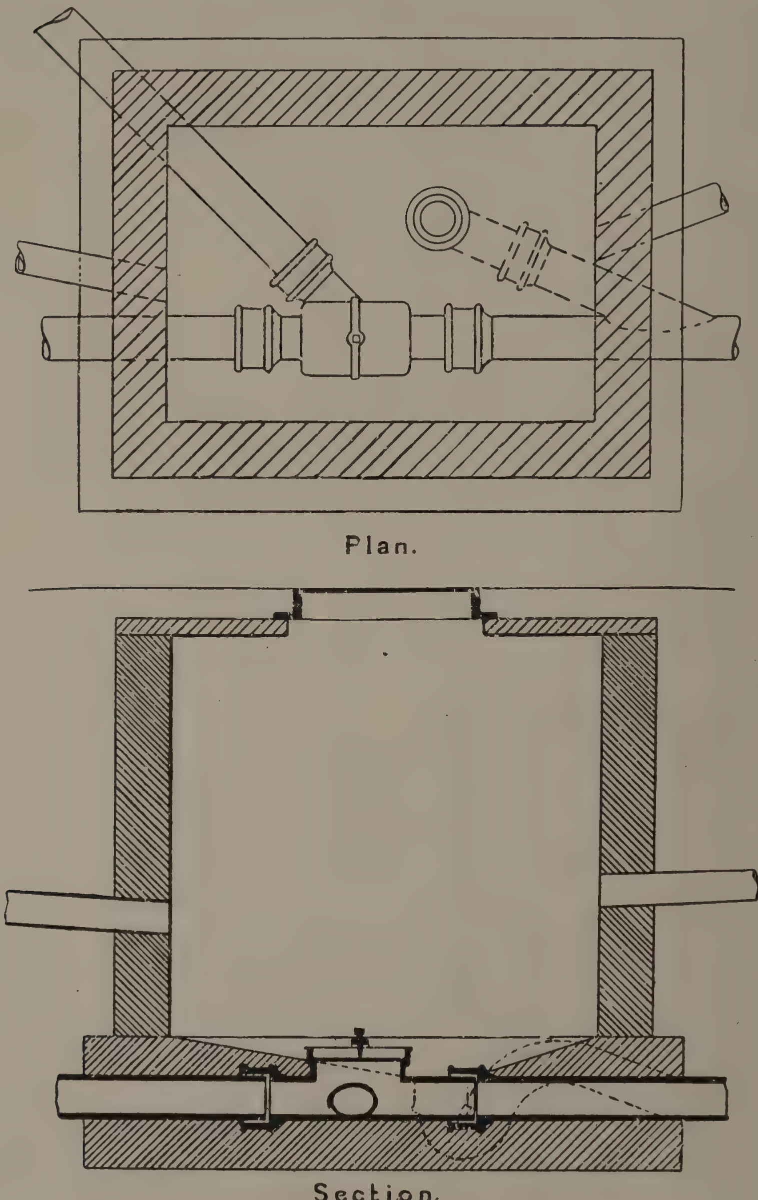

FIG. 37.—Manhole giving Access to Closed Pipe.

these should not be used where real tightness is wanted. Among their other drawbacks, it is difficult to provide satisfactory means of inspection. Openings similar to those in Fig. 36 are made, but of course the lids cannot be secured in the same way. If they were cemented down the pipe would probably be broken in cutting them out. Perhaps the least unsatisfactory method is to bed the lid on clay, fill up the space above the lid with sand, and cover everything with a thin sheet of cement mortar (Fig. 38). When necessary the cement is smashed up and removed along with the sand, and the lid then lifted. This is a poor plan compared with what can be done in iron drains.

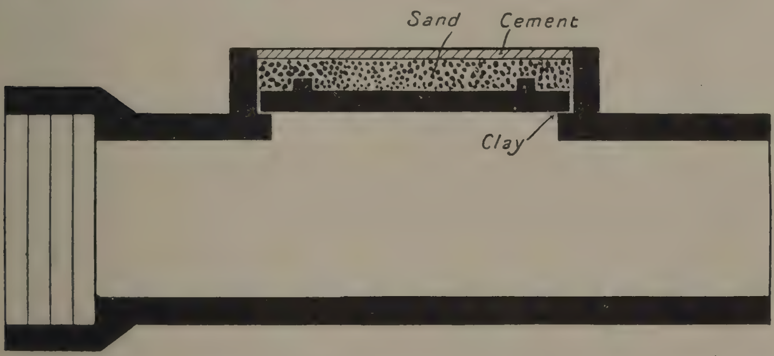

Fig. 38.—Inspection Opening on Stoneware or Fireclay Pipe.

Construction of Manholes.—When the manhole is shallow, so that the pipe cover may be reached by a man lying on the ground and inserting his arms, the size of the chamber may be correspondingly small. If the fastenings are not more than 18 inches from the surface, the manhole requires to be only big enough to give sufficient clearance round the pipe cover, and as a minimum this may be taken as 2 feet by 1 foot 6 inches. If the covers are large, more may be needed. Where it is necessary for a man to enter the manhole, the minimum size should be 3 feet by 2 feet 6 inches, and an extra 6 inches in length will often be convenient. The foundation is best made of concrete, and after allowing for the sloping of the floor and for a depth of 2 or 3 inches below the bottom of the pipe,

it will usually be found that the thickness under the walls is quite 12 inches. The walls are almost always of brick, $4\frac{1}{2}$ inches being a sufficient thickness for small, shallow manholes, while in ordinary ground 9 inches will serve unless the depth exceeds 12 or 14 feet. Of course if the manhole is unusually large this must be taken into account in deciding on the thickness of the walls. Where the inspection opening is a closed one, white enamelled brick is a mere extravagance, but pressed bricks neatly pointed, or ordinary bricks with cement plastering, may be desirable. In house drainage it is not often that subsoil water has to be specially considered, but it may be convenient to allow it to percolate into the manholes, and lead it away by the trap in the floor, as shown in Fig. 37, used also as a means of disposing of rain-water. A manhole of any depth should be provided with iron steps built into the wall.

Covers.—The lower cover being the one which confines any gases to the drains, there is no reason why that on the surface should be air-tight. All that is wanted is a plain cover of sufficient strength to support any traffic which may come on it. In house drainage two classes of cover are needed, one of them to carry any ordinary wheeled traffic, of which a coal cart or a removal van may be taken as the limit; and the other to carry only foot traffic, garden wheel-barrows, and the like. The heavier class of street traffic, such as traction engines, has not to be considered. It is not convenient to have the opening less than 18 inches either way, and 21 inches square, or 24 inches by 18 inches is preferable. If the manhole is sufficiently deep the brickwork is "corbelled" in so as to fit the cover: otherwise the opening may be covered partly by a stone slab (see Figs. 34 and 37). The upper surface of the cover may be chequered, or it may be recessed to hold concrete or other surface finish to correspond with its surroundings. It may be furnished with simple lifting handles in the form of handholes and bars, so that anyone may lift it without tools; it may require special hooks; or it may be hinged and locked; the particular form depending

on the place where it is to be put and the risk of unauthorised interference. Locking is not very satisfactory, as the key is seldom at hand when it is wanted. It is not uncommon to have walks, carriage drives, garden plots, etc., made up over the manhole covers, in which case the provision and retention of a drain plan—always desirable—becomes of special importance.

Number of Manholes.—This is usually the same as the number of inspection openings, but not necessarily so. Where an inspection opening is on a shallow drain, and where the ground is such that it could be opened with no great inconvenience, it may be worth while to save the expense of a manhole, although an inspection opening is provided. The inspection opening gives all the needed facilities for testing during construction, and the small chance of it ever being required on account of a stoppage may be set against the saving of cost. The chief risk is that when the emergency does occur the drain plan may be lost, and the digging results in reaching the drain at some place other than the inspection opening.

It is usual to provide inspection openings at every junction, and at every change of direction or of gradient. Further, if there are long stretches of drain on which this rule does not give a manhole, it is desirable to add others, so that there should be no greater length than 50 or 60 feet without some means of access. But circumstances differ so widely that no fixed rule can be laid down. At some junctions it may be quite safe to omit the inspection opening—as for example where a branch is trapped close to the main, with the trap at no great depth. If the trap should choke it can be cleared from the surface, while if the main should choke it can be cleared from one or other of the ends. If a stoppage occurred between the trap and the junction, it could most likely be forced from the trap. While full provision should be made for every reasonable contingency, it must be remembered that this provision introduces undesirable features—not to speak of expense—and that it should therefore never be in excess of reasonable requirements.

Inspection Openings on Pipes other than Drains. — Such openings are not systematically provided on pipes which are vertical or nearly so, but when on soil pipes or waste pipes there are long connecting pipes, which may be nearly horizontal, or where there are important junctions, it is common to provide means of access. These are seldom more than handholes, and as space is a consideration, the usual method of fixing is by gun-metal screws, in the manner illustrated in Fig. 39. As a rule, these covers are completely exposed, but they may possibly be under a hatch board in a floor. It is undesirable to have any such openings inside a house in any case, and it is specially undesirable when they are out of sight.

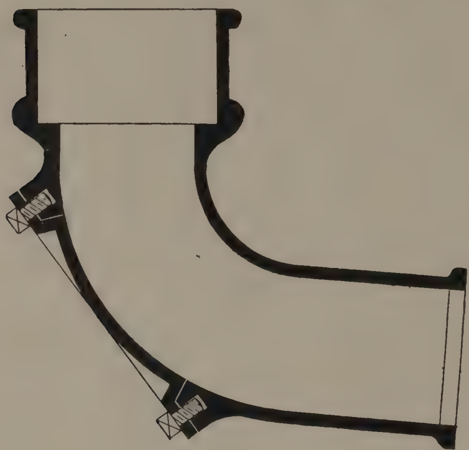

Fig. 39.—Handhole on Pipe.

CHAPTER XII

SOIL, WASTE, AND CONNECTING PIPES

These pipes form the connection between the fittings and the drain. The soil and waste pipes are usually vertical, and the connecting pipes (which in well-designed work are as a rule very short) connect these with the traps of the individual fittings. The distinction between soil and waste pipes and the extent to which separation is desirable have already been discussed (pp. 67 and 68), but whether a pipe conveys soil only, or waste only, or both, there should be no difference in the standard of construction. Each should be air-tight and water-tight, and all the precautions needed to ensure this should be rigorously enforced. The only difference should be in size.

Size.—It is a useful rule that no part of a channel should be of less size than the inlet; so that if anything is too big to pass freely through, it will not be allowed to enter. As experience has shown that the narrowest part of a closet trap should be about 3 inches in diameter, it follows that no soil pipe should be less. In practice, $3\frac{1}{2}$ inches is the size usually adopted as a minimum, though on the one hand 3 inches is not unknown, and on the other 4 inches is the most common. As between $3\frac{1}{2}$ and 4 inches, the latter is preferable when the pipe is of considerable height and with various connections, as it provides somewhat better ventilation for the drain. For a building of small height and where therefore the soil pipe is short, the smaller size is equally satisfactory. It is not many years since $4\frac{1}{2}$ inches was the standard bore, but except in unusual circumstances—such as may occur in public works or the like when a range of closets has to be connected—it is not often that anything larger than 4 inches is desirable.

Waste pipes are roughly proportioned to the amount of liquid which they have to carry, and recent practice is in the direction of making them larger than formerly, especially in the case of bath pipes. A bath may contain 30 to 60 gallons of water, and the rapid discharge of this is not only convenient, but of considerable value in flushing the drains. Instead of 1½ or 2-inch outlets, which were very common a few years ago, the best class of bath is now made with 2½ or 3-inch outlets, and the waste pipe should be no less. A 3-inch pipe may be regarded as the standard for waste pipes into which baths are discharged. It is not usually desirable to have any vertical pipe less than 2½ inches in diameter, even when the discharge into it is trifling—say from a lavatory basin or pantry sink. The advantage of increased ventilation outweighs the disadvantage of less concentrated flushing, the vertical fall making the flush fairly effective in any case. The connecting pipes from basins or sinks may, however, often be made 2 inches in diameter, or even less, but it must not be forgotten that changes may be made in the fittings from time to time, and as the tendency to use large outlets is not likely to diminish, it is desirable that the connecting pipes should have a margin of capacity. In tenement work, where there may be a series of sinks one above the other, the individual branches may be 2 inches, but the main waste pipe should be 3 inches in diameter.

Slop sinks should of course connect with the soil system. The connecting pipe should be 3 or 3½ inches in diameter, and if there is a vertical pipe it should be treated in all respects like a soil pipe. Urinals should never be fitted in private houses; their requirements when fitted elsewhere are dealt with in Chapter XV.

Position.—In Britain, such pipes are usually placed outside. They are thus readily accessible, and any defect is not only less dangerous, but is more likely to be promptly observed. In countries where severe winters are the rule the case is totally different, as the damage and inconvenience caused by frozen pipes would far outweigh the above advantages, and

there is no reason whatever why inside pipes should not be thoroughly safe. The outside position is enforced by most British local authorities, but while the balance may be in its favour, there is a good deal to be said on the other side. Winters are not unknown when serious inconvenience is caused by frozen pipes, and the experiences of the early part of 1895 will probably be completely overshadowed by those of the next similar frost. The amount of outside piping has increased immensely since then.

It has been argued that pipes should be inside, so that the increased temperature may cause a circulation of air in the system. This on the whole seems rather insufficient to counterbalance the advantages of putting the pipes outside.

There are certain recognised exceptions to the general rule. In reconstructing the drainage system of an old house it may be impossible without great unsightliness to replace the old inside pipes by new pipes on the outside, while on a street frontage it is undesirable to have pipes outside the general line of building. In such circumstances there may be sufficient reason for putting the pipes inside.

Of course, in cases such as these the pipes should be so arranged as to be readily accessible. The old fashion of burying pipes in plaster or concealing them behind woodwork should never be tolerated.

Shape.—It would be unnecessary to refer to this, were it not for another difficulty which sometimes occurs in remodelling an old system. In all ordinary cases it goes without saying that the pipes should be of circular section. But there are many buildings with old rectangular pipes on the outside; soil pipes, waste pipes, and rain pipes all having the same external appearance; and mouldings, cornices, string courses and the like being wrought round these pipes. In such cases it would be mere vandalism to use ordinary round pipes, and the difficulty may be quite satisfactorily got over by using pipes which are square or rectangular, but with all the inside corners rounded off. Fig. 40 shows such a pipe in section, and if it is made with sockets which will allow of thorough caulking, there is no

reason why any objection should be taken to it from a sanitary point of view. The branches will probably be at the back, and they should be of the usual shape and construction.

Material.—The general adoption of outside pipes has led to the use of cast iron and the abandonment of lead, the latter being now less used except for connecting pipes. The description given of iron drain pipes (p. 28) applies equally to soil and waste pipes, except that for these the thickness is generally quarter-inch. The method of jointing and the protective coating required for these pipes are the same as in the case of drains. The visible pipes may be painted of any desired colour on the top of the coating — the colour usually being that which will be most inconspicuous.

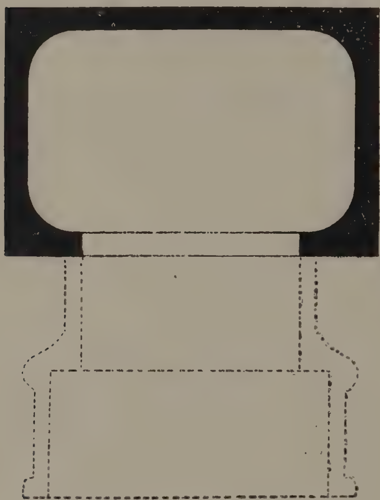

Fig. 40.—Pipe of Rectangular Outside Section.

Lead is still used occasionally for soil and waste pipes, and may be compulsory when these are inside. It has the advantage of being durable and smooth, but its softness renders it very liable to injury, and a nail hole in a lead pipe is a common accident. If rats can reach it either from the inside or the outside it is readily gnawed through. When lead is used, it should not be in any thickness less than the equivalent of "8-lb. lead," that is, a square foot should weigh eight pounds. Everything, however, should be "solid-drawn," that is, the pipes, traps, etc., are produced directly from the molten material, and are therefore free from the longitudinal joints which would be needed if they were formed from sheets. The joints should all be "wiped" or "round" joints (see Fig. 41), as the other joints do not give sufficient strength. It is impor-

tant that the lead pipe should be effectively supported at short intervals, as it is very liable to "sag" and even to tear away from its fastenings if these are too infrequent. Lead pipe is chiefly used in short pieces, and especially where bends have to be formed. These the plumber can readily make on lead pipe, whereas with iron elaborate fitting would be needed to make use of the unyielding material.

Fireclay or stoneware pipes are only used in exceptional circumstances, such as for waste pipes from chemical laboratories; and such waste should of course be kept quite apart from the ordinary drainage system.

Copper and brass have been used to a limited extent, but do not seem to have any special advantages, while their cost is a serious objection. Brass is freely used for connecting pipes in such places as public lavatories, and for the traps and down pipes of private lavatories; and if care is taken that the inside as well as the outside is smooth, it is a very suitable material. It has the advantage of appearance over both iron and lead, and has the further advantage over lead that it is less easily damaged.

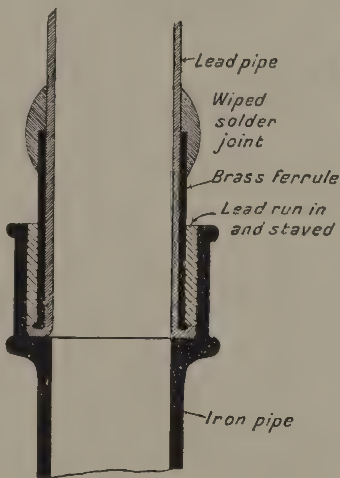

FIG. 41.—Brass Ferrule Connection.

Connection of Lead to Iron.—The only method which meets modern requirements is the use of a brass ferrule. Through this the lead pipe is threaded so as to project slightly at the lower end, and this projection is turned over or "tafted." At the other end a "wiped" solder joint is made; and the lead pipe, thus armoured, is slipped into the socket of the iron pipe. The ferrule is of such a length that it projects with its solder joint well clear of the socket, and it is of such

strength that it can resist the shock of staving. The joint is made precisely as if the pipes were both iron (Fig. 41). It is important that the lead should go completely through the ferrule, as it not only makes a stronger job but protects the brass from any contact with the contents of the pipe. The liquid comes in contact only with the lead and the bituminous or other coating of the iron, and galvanic action is thus avoided.

Ventilation of Soil and Waste Pipes. (See also Chapter on Trap Ventilation.)—The accepted rule is that every soil pipe should be carried above the roof, or at any rate above the eaves. This is desirable for various reasons—the gases which may escape are taken to a point from which they will not drift directly into windows or under eaves, the whole drainage system gets the benefit of the ventilation, and (in conjunction with trap-venting or sometimes as a substitute for it, see p. 163) it is a safeguard against trap syphoning. The utility of the rule is unquestioned; and the further regulation that the bore must not be reduced is also of undoubted value. Whether the pipe should go above the ridge or only above the eaves depends on circumstances. If there are skylight or other windows in the roof, or if for other reasons the lower termination would involve risk of gases entering the house, then the pipe should go above the ridge. It must on the other hand be noted that bends are to be avoided, and a pipe carried vertically 2 or 3 feet above the eaves may be more effective than one which reaches the ridge by several bends. Each case must be judged on its merits.

Waste pipes should be treated exactly as soil pipes, and the upper termination should follow the same rules. It is very unsatisfactory to have waste pipes terminating, as they too often do, in such a way that any gases can readily blow into windows. The fact that disconnection tends to such negligent design is a strong argument for its abolition.

It happens occasionally that, owing to sanitary fittings being placed in a wing of less height than the main building, it is difficult to carry the air pipe high enough to clear the latter.

The difficulty may be met by bending the air pipe away from the main building and ending it with a bell mouth, the result being that when the wind blows toward the main building it blows down that particular pipe, and it is only when the current is blowing in some other direction that any gases escape from it.

Protection of Openings.—Some protection of the upper end is necessary, otherwise birds will soon have the pipes choked with their building material. Nothing is more effective and nothing is less conspicuous than the wire ball or cage which is now commonly used (Fig. 42). It is best made of copper wire, and requires no fixing other than pushing the projecting wires into the mouth of the pipe. It obstructs very slightly the passage of air, and it is readily removed when necessary; as, for example, when the end of the pipe is to be plugged for testing purposes. The elaborate lead terminals which are occasionally found may be a serious difficulty when circumstances necessitate their removal.

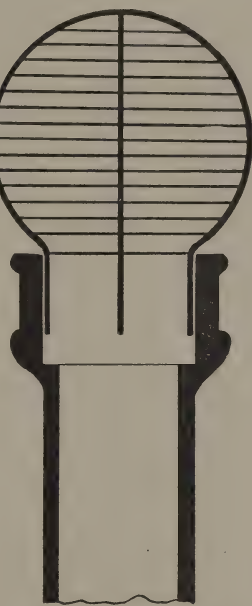

Fig. 42.—Wire Ball Grating.

Extracting Ventilators.—These are sometimes found on the top of soil pipes, the idea evidently being to determine the air-current upward and prevent any escape of drain gas at the "inlet" ventilator. This advantage is rather a shadowy one; and as a rush of air down the pipe naturally follows every discharge of water, any hindrance to this rush is an objection, and may lead to trap syphonage.

CHAPTER XIII

WATER CLOSETS

Action of Flushing Water.—In the water carriage system the excretal matters are not only removed by the agency of water, but they are received into a body of water in such a way as to prevent if possible the fouling of the receptacle. While every modern type of closet has an arrangement for running clean water through it, it is to be specially noted that in some types the rush of this incoming water is the chief agent in removing the excreta, while in others this work is chiefly done by the fall of the water already in the closet.

This distinction is of great importance, and has not received the attention which it requires. Its importance is greatest when the water supply is limited, and this is by far the most common condition under which closets have to work. If the receptacle is to be cleared by the incoming water, the first work which that water has to do is to set in motion the whole contents, including the contained water. The less there is of this the easier will be the work of the incoming water; if the contained water is in large quantity, then the incoming water must either be in large quantity or must come in with high velocity. The latter is barred because it would cause splashing; and therefore a closet which depends for its efficiency on the rush of incoming water, and which itself holds much water, must have a large volume supplied to it. If this large supply is impracticable, either the amount of contained water must be diminished, or the work of emptying must be done to a greater or less extent by the contained water itself.

The reduction in the volume of contained water is limited by the consideration that if there is too little water the basin is certain to be soiled. A sufficient "water area" is one of the requirements of a satisfactory closet, and as a thin sheet of

water is not sufficient, this implies a considerable volume. The problem of designing an apparatus which will give a fair water area, which will be effectively washed out by the rush of the incoming water, and which will do this with a supply of water not exceeding two gallons, is so full of contradictory requirements as to be almost insoluble. When three gallons can be given for each flush the difficulty is much reduced, but there are many places where two only are allowed.

Long before any specific allowance of water was laid down the tendency was to economise water, and inventors had been at work to design an apparatus which would act with the least expenditure of water and with an appearance of efficiency. Until a comparatively recent time apparent efficiency only was regarded—that is, if the offensive substance passed out of sight without actually choking the passages, no one cared whether or not it left a trail of pollution behind it. Hence the prevalence of such arrangements as the notorious "pan" closet.

In designing an apparatus to work with a limited quantity of water, the old inventors went on the sound lines of making the contained water rather than the incoming water do the work, and this naturally took the form of mechanical contrivances to allow the contained water with its contents to fall from the original receptacle. The older types, therefore, almost without exception, came under the heading of "Mechanical" closets. The modern objection to allowing any mechanism to come in contact with the contents of the closets led to the introduction of "non-mechanical" closets, most of which depend on the incoming water to do the work. It will be convenient to classify closets into mechanical and non-mechanical, according as the apparatus itself has or has not any moving parts. The arrangement for supplying the water is not for this purpose regarded as part of the closet.

The number of different appliances which have been designed by various manufacturers is enormous, and any detailed consideration of these would be impossible. It is the general principle rather than the individual application that will be considered here.

Closets with Moving Parts.—In these a passage is opened through which the contents pass by gravitation, with more or less assistance from the water which is delivered to the closet by some connected mechanism. The passage is opened by the movement of a pan, a valve, or a plunger, and the closets will be considered under these three classes.

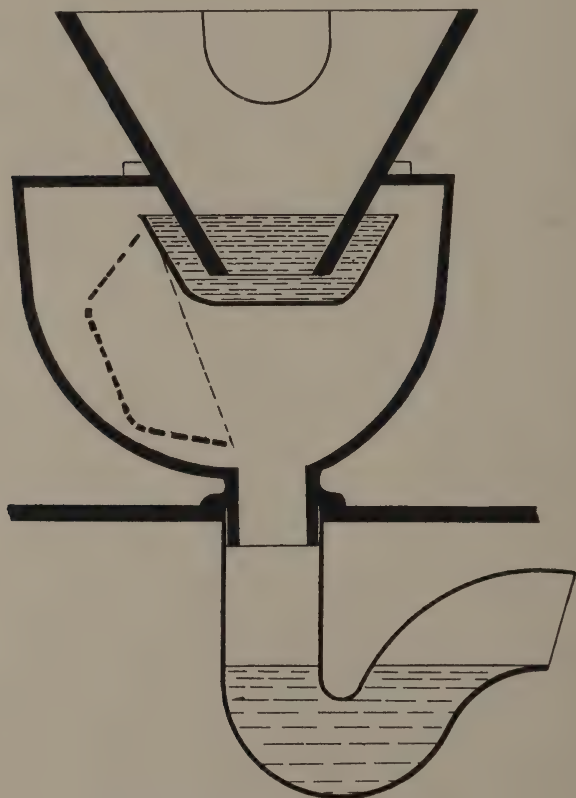

Fig. 43.—Pan Closet.

Pan Closets (Fig. 43).—These are, and have been for at least thirty or forty years, condemned by all sanitarians. The basin has its outlet closed by a movable copper pan which discharges its contents into the "container" or "trunk" when by the action of the handle and lever the pan is brought into

the position indicated by the dotted lines. The apparatus is utterly filthy, and ought to be absolutely condemned whenever found. No house containing such an appliance should be passed as fit for human habitation, and while at one time there was some hesitation in taking strong measures there ought now to be none.

It will be noticed that in this and some of the other mechanical closets the trap is not part of the closet, but has to be provided separately (see p. 117).

Valve Closets. — The "Bramah" closet is the standard from which many varieties have been developed. Its main features are shown in Fig. 44, and while the original invention dates from 1778, these remain the same to the present day, though of course in detail the modern valve closet differs from the original "Bramah" in many respects.

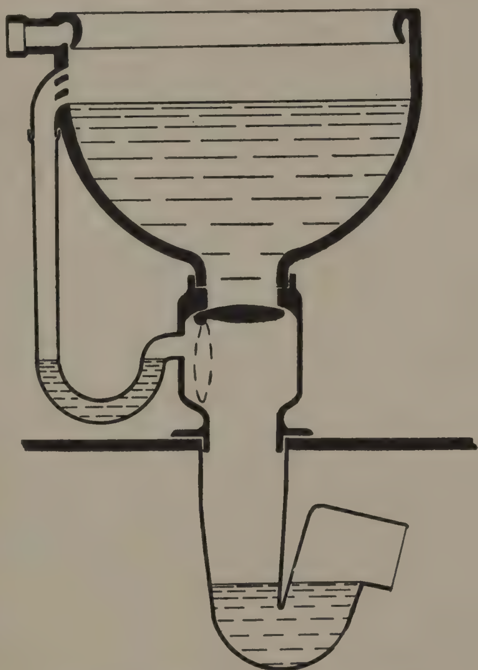

Fig. 44.—Valve or "Bramah" Closet.

The basin, which is usually hemispherical in form, is closed by a tight-fitting valve. It holds a considerable volume of water, and when the valve is opened the removal of the contents is effected by the water actually in the basin. The valve chamber is small, the contents of the closet drop almost vertically through it, and the rush of water is fairly effective in keeping

its inner surface clean. The large volume of water in the basin keeps its surface from being soiled. A first-class closet of the "Bramah" type meets to a large extent the requirements of modern sanitation; and while these are not now commonly installed in new buildings, or in old buildings which have to undergo a sanitary overhaul, there is no inherent reason why such a closet should be taken out so long as its condition is good.

There are, however, certain disadvantages. The chief of these is that the mechanism usually involves a wooden casing, and this is counter to all modern ideas of sanitation. It is quite certain that in some houses such an arrangement will be kept spotlessly clean, behind the casing as well as in front of it; but it is equally certain that in the great majority of houses this will not be the case. Again, even the plainest type of valve closet must be of good material and workmanship: this means that it is costly, and if the various refinements and improvements which have been introduced into the most recent makes are included, the cost is considerably increased. It is not, therefore, a closet which is suited for general use, and it requires much more care and attention than would be necessary for the non-mechanical type of closet.

If such a closet is used at all, the following points should be kept in view:—The frame should be sufficiently large to give suitable points of support for the mechanism, and sufficiently strong to be durable and stiff. The valve motion should be such that the valve will open cleanly and close tightly, without any severe drag on the lever; and the spindle and stuffing-box must be strongly made and well fitted. The water supply must be so arranged that the water continues to flow after the handle has been released and the valve closed, so that the basin will be filled to a suitable height (see p. 127).

Such closets are necessarily provided with an overflow, and this should join the trunk immediately behind the valve, so that the opening of the valve protects the end of the overflow from pollution. It is important that water should frequently pass through the overflow pipe, both to keep it clean and to

keep its trap supplied, and this is most commonly provided by delivering rather more than is required to fill the basin to the overflow level. It is well, however, to have the incoming water so delivered that some of it will pass into the overflow as it enters the basin, irrespective of the quantity of water in the basin.

The valve closet has usually a complete covering, sometimes of elaborate cabinet work, and this, an objection at all times, is specially so unless it can readily be removed.

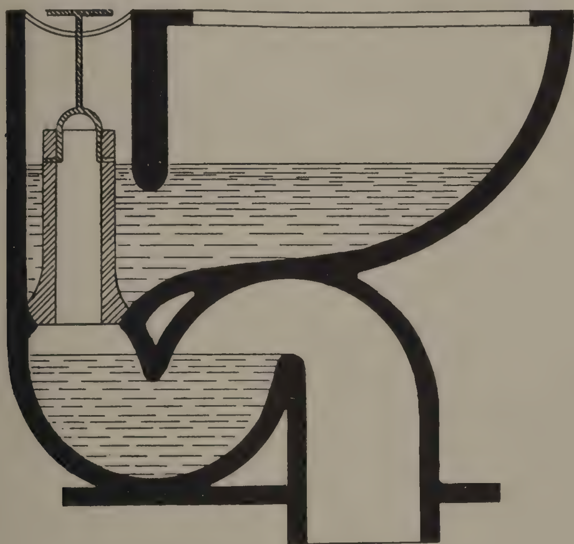

FIG. 45.—Plunger or Plug Closet.

A modification of the valve type has been introduced, under the name of the Pedestal Valve Closet, in which the mechanism is disposed in such a way as to render the wood boxing less essential.

Plunger or Plug Closets.—These are seldom satisfactory, though the better makes may by care and attention (including occasional dismantling for thorough cleaning) be kept in surprisingly good order. The basin outlet is to the side, and leads into a second chamber of which the bottom is closed by

a plunger (Fig. 45). When this is lifted the contents of the basin pass through the side outlet and then down. The side chamber is exposed to contamination by foul matters, and is not effectively flushed. The plunger is often made hollow, and serves as an overflow, the inside being sometimes shaped to form a trap; and this form of closet has frequently been fixed without any water trap, having at one time had a considerable vogue as a "trapless" closet. The supply of water is sometimes controlled by a ball valve in the side chamber, but as this also is exposed to pollution, it is a distinct aggravation of the inevitable objections to the plunger closet.

Closets without Moving Parts.—In all the closets already mentioned two mechanical actions are necessary, one to actuate the pan, valve, or plunger; and the other to bring in the flush of water. As regards the user the two actions are combined, as the lifting of the handle commands both; but it is evident that if some contrivance could be devised whereby the inrush of water could empty the closet, it would be possible to do away with all mechanism about the closet itself.

There are two methods by which this can be done, and each of these has been adopted in practice. The first is to make the outgo of the closet in easy curves, and to bring in the water with considerable velocity and in considerable volume, so that its momentum would carry the contents away. The other method is to have a body of water in the basin, and to remove this by syphonic action, the action being started by the inrush of the flushing water.

Comparison of Momentum and Syphon Action.—When the momentum of the incoming water is to be used, it is evident that the less the basin holds the better. The motion of the incoming water has to be imparted to all the contents of the basin, and the water contained in the basin is thus a direct check on the action. The more water at rest in the basin and trap (whether these are combined or separate) the more momentum is required in the incoming water. This momentum may be

given either in mass or in velocity; but these, as already explained, are both limited. To make the most of the limited momentum, the best that can be done is to introduce the water in large volume during a short time, that is, the supply pipe is made large at the expense of the flow being shorter.

The syphon action, on the other hand, does not necessarily depend on momentum. If the required reduction of pressure on the outgo side can be obtained, the atmospheric pressure on the exposed surface will clear the closet effectively, the power being far in excess of what is required. Given, therefore,

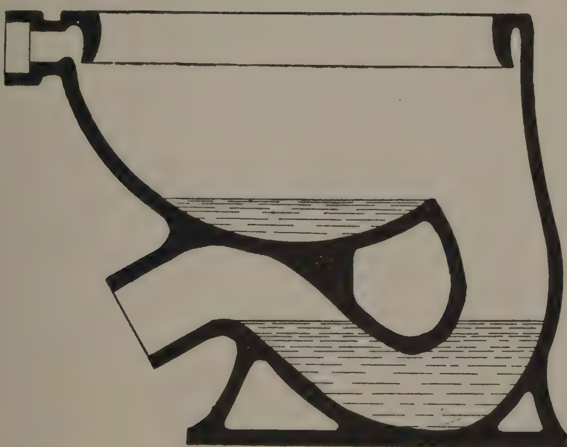

Fig. 46.—Washout Closet.

equal simplicity and freedom from contingent disadvantages, the syphon closet would be decidedly preferable to the momentum type. Meantime, however, the greater simplicity of the latter has made it far more common. The detailed consideration of each type follows.

Momentum Closets :—*Washout Closets.*—These do not require any detailed notice, as they are practically obsolete. Fig. 46 shows the general type in one of the least unsatisfactory shapes.

The excretal matters are received into a shallow basin, the

outlet from which is over a weir into a trap. The flushing water has to carry the contents of the basin over the weir and through the trap. There are thus two bodies of water to which motion has to be imparted. The water in the basin is too shallow and too limited in quantity to protect the surface from being soiled, and the part of the closet opposite the weir and above the trap is constantly fouled by the matters which are splashed against it.

Although the conditions are not nearly so bad as in the "pan" closet, where the same fouling is unaccompanied by any washing, it is found in practice that the rush of water does not prevent the gradual fouling of all the surface. When the closet was first introduced it was very popular, as the trap was out of the ordinary line of sight and the basin looked strikingly clean; but this apparent cleanliness was illusory, and the washout closet is rapidly falling out of use. It is specially unsatisfactory when the water supply is small, as it often happens that the flush is insufficient to clear the trap as well as the basin, and matters are left floating in the trap.

Washdown Closets.—In these the basin and trap are in one, there is only one body of contained water, and the incoming water has only to force the contents through the trap. At the present time this type of closet is by far the most common, and, on the whole, its work is reasonably satisfactory. The varieties in detail are almost unlimited, but the practical differences are comparatively few, although there is a great difference in the working of a well-designed closet as compared with one in which nothing but cheapness has been considered.

The basin should be shaped so as to give a large water surface, otherwise soiling of the uncovered surface is sure to occur. For the same reason the back is made with a very slight forward inclination from top to bottom, or with none, or even (as illustrated) with a slight inclination backward. For the reason already explained, the large water surface should not be accompanied by a large water capacity, and the curves should be such as to allow the contents to be swept smoothly

through the trap. Fig. 47 shows the general shape of a modern type of closet.

The flushing water must be properly distributed, so as to wash down the sides of the basin, and at the same time to leave no eddies. The earlier closets had merely a lead " fan " or " spreader " behind which the water entered, and by which it was directed round the basin, as indicated in Fig. 43. This was superseded by the " flushing rim " formed in the material of the basin, and shown in Figs. 44, 46, and 47. This was first applied to " Bramah " closets, and then to washout and

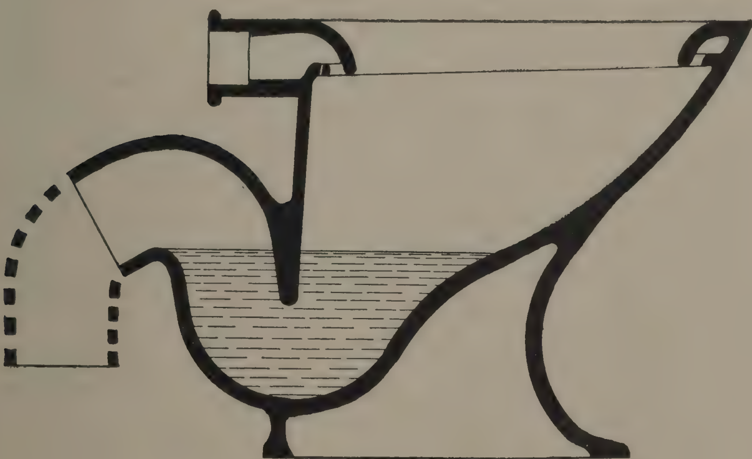

FIG. 47.—Washdown Closet.

washdown. In the washdown it was found that when the water surface was large there was a risk of matters being left floating in the middle of the basin after the flush had passed. The flushing rim round the basin therefore usually includes some arrangements by which the water is directed over the central surface as well.

The delivery of the flushing water to the closet is dealt with later (Chap. XIV.).

The term " Hopper closet " is sometimes applied to any washdown closet, but it is more properly and usually applied only to an early and now disused type in which the basin was

of a simple conical shape. In a "long hopper" the basin reached the floor, and the trap was below the floor; in a "short hopper" the basin and trap were both above the floor. A basin of this shape could not be kept clean by flushing, and as the flush was frequently a small flow through a spreading fan, from which the water wound down the basin in spirals, the result was usually very bad.

Syphonic Closets.—Any closet whose trap curves down from the outgo with sufficient quickness, and which is not provided with an "anti-syphon" pipe, may act as a syphon; this being one of the well-known accidents by which traps become ineffective. The difficulty, therefore, is not to produce the syphonic action, but to keep it under proper control.

The action of the syphonic closet is dependent not on the incoming water, but on the water already in the basin. The incoming water starts the syphon, assists in washing out the basin, and fills it up to the required height after the syphon action is over; but the actual removal is done by the contained water. There is thus no reason, as there is in the washdown closets, for limiting the amount of contained water; when the syphonic action is started, the air-pressure on the upper surface provides ample power to force it out.

The syphon action might, of course, be set up by some agency apart from the incoming water, but, as a matter of practice, it is usually done in this way. The water is either led altogether into the basin as in a washdown closet, or it is partly delivered through or above the trap, or between two traps. In the first case, the rush of water causes an overflow into the descending leg of the syphon, sufficient to start the action; in the other the air is displaced by a jet of water introduced either at the bottom of the trap or at the top. The former, illustrated in Fig. 48, is the simpler and on the whole better way. This closet (Shanks's "Barrhead Syphonic") has an exceptionally deep trap, and the air pipe for trap ventilation is placed sufficiently far down from the top to allow the syphon to act without any interference. When the syphon first comes

into action the closet basin is emptied with great rapidity, and although the flushing water continues to run in, it is insufficient to keep the syphon charged. It therefore draws air from the basin into the syphon, the syphon action is broken, and the remaining water fills up the basin. When everything is properly adjusted, the action is remarkably effective. It is necessary, however, to have the capacity of the cistern and the size of the service pipe so arranged that the water will

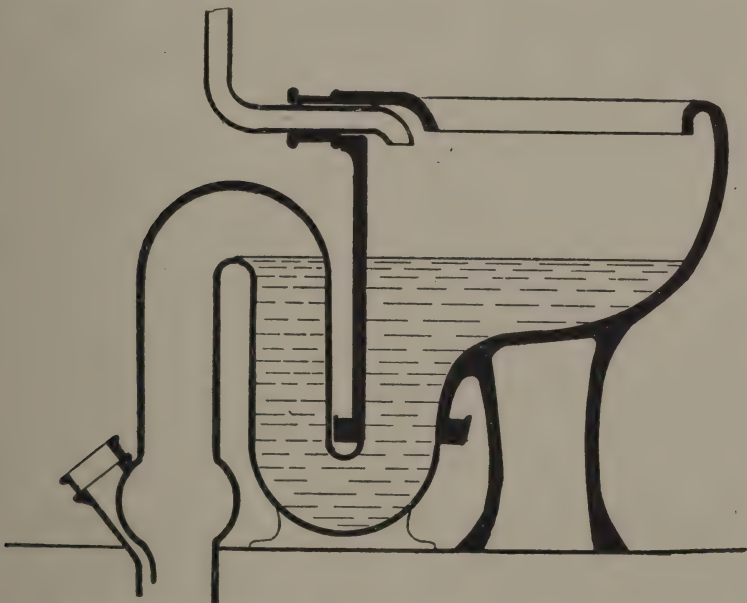

Fig. 48.—Syphonic Closet. (By permission of Messrs. Shanks & Co.)

come in at first with sufficient rapidity to ensure that the syphon will start, and that towards the end of the flow it will stop before the syphon has been started for a second time. In practice it is found that with reasonable care there is no difficulty in securing this. An objection has been made that there is a momentary loss of seal in the trap. This is true, but as it occurs because of the rush of water from the basin into the pipe, and as the air which passes is going in the same direction, it is an objection of no weight.

There is, of course, the possibility that syphonic action might be set up by the discharge of water into the basin in some other way—a pail of slops for instance. Such closets are not well adapted for use as slop sinks, and should not be installed where they will frequently be so used; but as the only result of an occasional discharge would be that the basin would not be properly filled up for the next use, the objection is not a very serious one. The discharge of a pail of slops might start the syphon, but the depth of the trap is such that the stop of the syphon action would result in enough water falling back from the rising leg to seal the trap effectively.

This form of closet has two casual advantages. One is that the trap is of a much greater depth than is otherwise practicable; the other is that the connection between the earthenware basin and the lead trap is under water. If, therefore, there is any leakage, it at once becomes visible, and the chance of drain air entering the house by an unnoticed crack disappears.

Another type of syphonic closet is started by a jet of water, introduced outside the ordinary trap but above the supplementary trap. This introduces some complication, as the incoming water has to be divided, and the cistern is in connection with a part of the apparatus beyond the ordinary trap. The provision of a special trap on the service pipe is not altogether a satisfactory way of meeting the difficulty, and, on the whole, the simpler arrangement already described seems preferable.

Devices have been sometimes used to ensure that when the syphon was started otherwise than by pulling the handle the cistern would be automatically discharged. This is in itself a desirable thing, but it has sometimes led to the service pipe being put in communication with the discharge pipe beyond the trap. In all sanitary appliances simplicity is of the utmost importance, and it would be something of very great value that would justify making any connection to the discharge pipe, either from the cistern or any other part, on the outgo side of the trap.

Closet Traps.—In the older forms of closet the trap was altogether separate. The pan and valve closets required to have a trap under the floor (see Figs. 43 and 44); the plunger closets were usually made in the same way (though sometimes a trap was not used at all, and sometimes it was above the floor); and the hopper closets had a separate trap, above or under the floor according to the length of the hopper. In the more recent closets, on the other hand (except some types of syphonic closet), the trap is part of the closet and made in one piece with it. The lead closet trap is now uncommon, except the special traps of some syphonic closets.

It is unnecessary to do more than mention the D trap, which shared with the pan closet the unenviable distinction of being the most insanitary contrivance ever invented. In some parts of the country it appears to have been the almost inevitable companion of the pan closet, and is often so described in text-books. Its geographical distribution, however, must have been far more limited, as in the experience of the author not one per cent. of the pan closets he has seen were fitted with D traps. Their popularity was partly due to their supposed power of resisting "syphonage" but chiefly to the power of custom. Trap syphonage was quite possible in the case of a valve closet if the ventilation arrangements were inadequate, but was very unlikely to occur even with a round pipe trap if it were properly ventilated, and still less likely to occur if a trap such as Hellyer's Anti-D trap (shown in Fig. 44 under the valve closet) were used. The state of non-ventilation which would permit of syphonage with a pan closet was scarcely conceivable.

In the rare cases where separate traps are now required it is seldom necessary to use anything other than the "solid-drawn" round pipe trap (which is illustrated in Fig. 43 in conjunction with the pan closet), taking care that it is effectively ventilated (see p. 162). If for any reason the chance of syphoning, or rather of emptying through momentum, is specially great, then the anti-D trap may be used.

Connection of Trap to Soil Pipe.—Whatever may be the form of the lead trap, there is no difficulty in connecting it to the soil pipe system, as a wiped joint secures it effectively to the lead connecting pipe, and a ferrule connection completes the junction with the iron. The closet is connected to the trap without danger, as the connection is on the other side of the trap and protected from drain gases by the trap itself.

When the trap is in one piece with the closet the conditions are entirely different. The joint has to be made on the outside of the trap, and it has to be made between two dissimilar materials. The most common connection is the

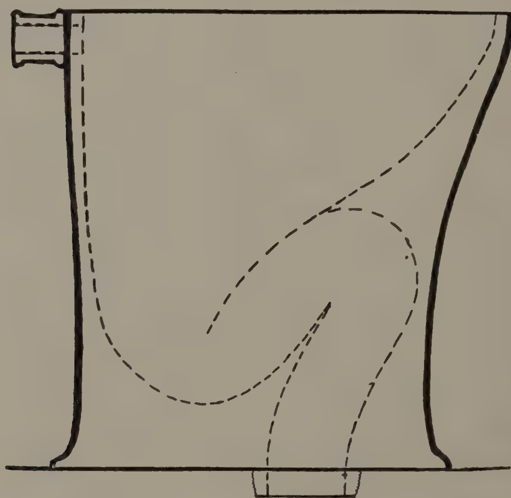

FIG. 49.—Closet, with joint inaccessible.

"slip" joint, in which the projecting outlet of the closet is slipped into the mouth of the lead pipe, and packed round with putty. At best this is a poor job, but it has degrees of badness. When the closet outlet is so placed that the joint is at floor level, right under the base of the closet (Fig. 49), the joint is largely a matter of chance, and good or bad there is no getting at it. It is much better when the joint is above the floor and clear of the closet body, either by the use of a "shoot out" trap (see Figs. 46 and 47), or by a turned-

down trap stopped short of the floor, as indicated by the dotted lines in the latter figure. It is then possible to improve the joint by putting a metal strap with tightening bolts (sometimes called a "gland") round the lead.

Many attempts have been made to supersede the putty joint, and by far the most successful of these was that of Doulton, whose "metallo-keramic" joint has now for a long time been the standard of excellence. In the process of manufacture a soldering flux is fused on to the earthenware, and the closets are sent out with a short length of lead pipe attached. One end of this pipe is securely soldered to the earthenware, the other is ready for the plumber to connect as he would any other bit of lead pipe.

In some washdown closets the trap has been made of lead or of iron, so that the connection between the dissimilar materials should be on the house side of the trap or under the water. This was rather objectionable on the score of appearance, as the dark colour gave a dirty look to the whole appliance. In the case of the deep and narrow trap of the syphonic closet (illustrated in Fig. 48) this is immaterial, as it is scarcely possible to see the lead.

At one time it was quite common to make the basin and trap of washdown closets separate, even when they were both of one material. The advantage was that in the case of accidental breakage it was cheaper to replace the one part than the entire closet, but the extra joint was a serious objection. The custom has fallen very much into disuse.

General.—Leaving the question of closet cisterns for consideration in the succeeding chapter, there are several general points to be noted:—

Material.—The material of which the closet is formed should be non-absorbent and easily cleaned. White earthenware and white enamelled fireclay are usually adopted, the former for places where careful use is to be expected, such as in the better class apartments of private houses; the latter where strength is of more importance than appearance, such

as public lavatories, schools, and "outside" accommodation generally.

Outside Appearance.—This cannot be too plain. The coloured designs, embossed patterns, and heavy mouldings which were much favoured a few years ago served no purpose but to harbour or conceal dirt—and to advertise the bad taste of those who were responsible for them.

Seats.—The elaborate cabinet fittings passed with the passing of the mechanical closet, and the seat is now a mere rim. In the best class of closet it has no fixture except to the closet itself; the back of the closet is made sufficiently strong to give it support by means of a couple of bolts, and the whole apparatus is thus entirely detached from the wall. For a time the double seat—a flap hinged to the actual seat so as to cover the opening when lowered—was a popular arrangement, and even now is frequently used, apparently from some idea that it looks better. It is anything but an advantage, as water is apt to get between the two, and in any case it hinders the free aeration which is desirable. Its only excuse is in those cases where the closet and bath are in one apartment, and where it is convenient to provide a seat which may be used by the bather while dressing. From a sanitary point of view it is bad, and it offends the trained eye. For schools and public places even the hinged seat is falling out of use in favour of the "inset," which reduces the extent of possibly absorbent material to a minimum (p. 160).

Slop-water Closets.—These should never be tolerated. They accumulate filth in one receptacle and dirty water in another, until the accumulation of dirty water is sufficient to turn over a "tipper," thereby discharging the dirty water to wash away (more or less) the accumulated filth. The system is a direct violation of every principle of sanitary construction. It is defended because it is said to economise water and to save trouble from frost. But water economy gained at the cost of accumulating solid and liquid filth is radically bad, and the

danger from frost should be otherwise met. Such closets seem to be popular in some parts of the north of England. They do not seem to be common in the south, and in Scotland they are unknown. While it is true that in Scotland water is usually more plentiful than in England, it is also true that frosts are more severe. The danger from frost has not led to their introduction there, and can scarcely justify them in any other part of Britain.

CHAPTER XIV

FLUSHING CISTERNS AND PIPES

For ordinary household use it is desirable that water should be drawn direct from the main, without the intervention of any cistern. Storage cisterns are only used when the supply from the main is intermittent or unreliable.

Cisterns, however, are required to supply the hot-water system, and for closet flushing. In the one case the object is to regulate the pressure, in the other there is the double object of preventing waste of water and of protecting that in the pipes from possible contamination.

Waste Prevention.—Flushing cisterns are frequently known as "Water-waste Preventers," but the name which indicates their primary rather than their secondary purpose is to be preferred. They are usually of a size to contain only the amount of water required for one flush, and are fed by a small pipe through a ball-cock. It is thus impossible to discharge more than the fixed quantity, and in order to get a second discharge it is necessary to wait till the cistern again fills. Further, the discharge arrangement of the small cistern is usually such that it cannot be permanently set open, even by design—that is, an actual impulse must be communicated to the apparatus by hand for each discharge.

As compared with the old arrangement of a simple valve in the bottom of a large cistern (see Fig. 52) from which water continued to run so long as the valve was kept open; or with the stop-cock from the main (or main storage cistern) which might be left permanently open, the small cistern obviously effects a great economy. From a sanitary point of view there is not the slightest objection to this, so long as the flush given by the small cistern is sufficient to do its work. A dribble, however long continued, is of no value.

Protection from Pollution.—When flushing water is taken direct from a cistern which supplies water for ordinary household purposes, there is the chance of pollution by gases passing up the connecting pipe. There is also the probability that in choosing the position of the storage cistern the convenience of the closets rather than the purity of the water will be kept in view, and that the water may absorb gases from the apartment itself. If the closet obtains its water supply by a valve at the closet itself from a pipe which serves other purposes, the dangers are still more serious, and cases have been recorded where liquid from the closet basin actually entered the water pipes. There is, therefore, no difference of opinion between water authorities and sanitarians as to the advisability of special flushing cisterns.

Size of Cistern.—On the question of size, however, there is a sharp conflict between many water authorities on the one hand and practically every sanitarian on the other. This is specially the case where the water supply is in the hands of a company; where it is under the control of the public authorities there is usually less difficulty. The difference has practically been narrowed down to a question of one gallon—the capacity of two gallons for the cistern being almost invariably admitted, while sanitarians consider that three gallons would be a reasonable if not an ideal allowance. The former is an absurdly small supply when it has not only to clear the closet basin but to convey the contents through, it may be, a considerable length of drain; the latter is by no means excessive, but may be regarded as a fair compromise. Nothing less than three gallons should be used unless as a matter of necessity, and when there is no difficulty about the provision of water, it is judicious to allow more. Experiments on the clearing effect of various quantities of water have been made from time to time, but the conditions vary in so many ways that really conclusive experiments are scarcely practicable, and experience remains the chief guide.

It has been suggested that the undue restriction of closet flush is a mistaken policy, as careful users will repeat the flush

again and again. Unfortunately the careful users who will do this are so far outnumbered by the careless that the financial balance is no doubt on the side of the niggardly policy.

Method of Discharging Cistern.—This should be simple and uniform as well as effective, so as to give no chance of confusion even among people of very low intelligence. A simple valve, opening when the handle is pulled and closing when it is released, is not satisfactory, as it may be released too soon; it is necessary to have an arrangement which when once started will continue till the cistern is empty, whether or not

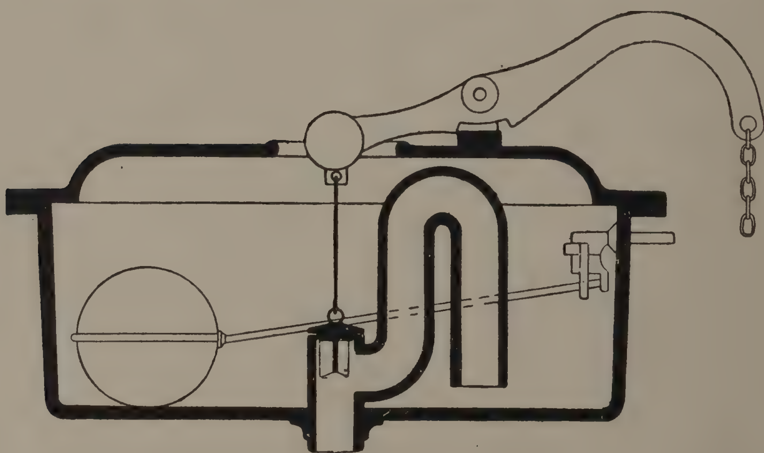

Fig. 50.—Valve Syphon Cistern.

the pull is continued. The handle must be pulled and let go, with or without an interval between, and while in some forms of cistern the discharge is started by the "pull," in others it is by the "let go." There is no intrinsic reason for preferring one to the other, but as most people are accustomed to the former, and expect the water to come before they let go, it might be as well that the former should be recognised as the standard arrangement.

However the discharge is produced, it is essential that it should be certain. A cistern which discharges well with a sharp pull but not with a slow one is quite unsatisfactory,

and a cistern which under some circumstances allows a dribbling discharge of its contents is worse.

Syphon action in some form is usually adopted. A very simple arrangement is that shown in Fig. 50, where the pull raises a valve from its seat, and allows a direct discharge so long as the valve is held open. If it should be released before the cistern is empty, the syphon completes the discharge. If the valve is kept continuously open the water runs through the cistern to waste, so that this arrangement does not comply

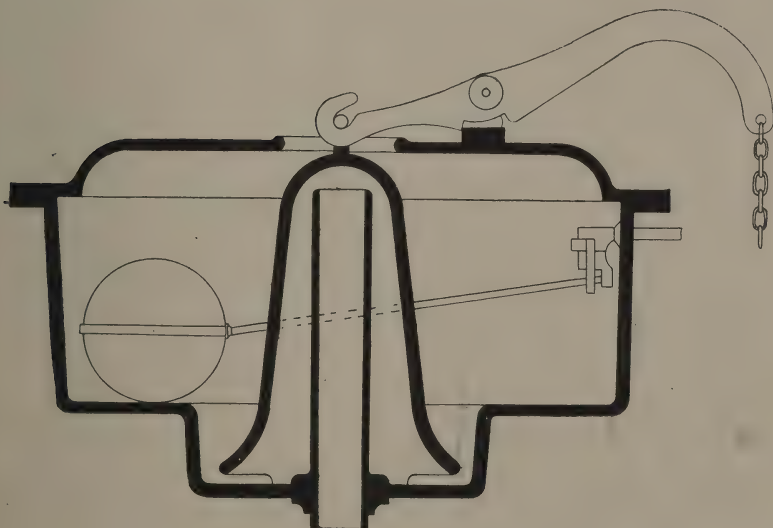

FIG. 51.—Valveless Syphon Cistern.

with the usual requirements of water authorities; otherwise it is quite satisfactory.

The most common type is that in which there is no direct passage through the cistern. The water can only be discharged by the action of the syphon, and as the top of the syphon is above the water level fixed by the ball-cock a direct impulse given by hand is needed for each discharge. The methods of doing this are many, but mostly depend on the more or less sudden movement of a part of the apparatus, by which movement some of the contained water is thrown

over the syphon. Fig. 51 illustrates how this is done in one of the numerous types. The moving bell is a loose fit, and it is quite possible to move it slowly without starting the flush. The clearance must therefore be adjusted so that any ordinary pull will be certain to start the action. Of course any action which depends on impulse may fail if the impulse is extremely slow.

Noise of Discharge.—In the ordinary syphon cistern there are several causes of noise: the rush of the water into the basin of the closet, the drawing of air when the cistern is emptied, and the hiss of water through the ball-cock as the cistern again fills. The first of these is an unavoidable accompaniment of the system; the second may be reduced to a minimum by allowing the air to enter very freely so as to avoid any long-drawn sound; and the third can be almost stopped by proper precautions. These precautions imply (1) the provision of a stop-cock behind the ball-cock, so that the pressure may be regulated before the water reaches the latter; and (2) the provision of a cover for the cistern. The cover of course must not be air-tight, or the syphon action would be checked. The provision of a deafening pipe, by which the discharge from the ball-cock is taken to the bottom of the cistern, is not looked on with favour by the water authorities, on account of the risk that water might be sucked back into the pipe. The material of which the cistern is made has a considerable effect on the noise.

Material.—For the sake of cheapness, cast iron is most used. It is not specially suitable, as it requires a protective coating—which may or may not be permanent—and it acts as a resonator and exaggerates the noise. The usual protective coating is zinc, the cast iron being galvanised; but on the one hand ordinary paint and on the other glass enamel are frequently used. The failure of the coating leads to the rapid deterioration of the cistern by rusting, and this has the further effect of discolouring the water and possibly staining the closet basin. For work where cheapness is not an urgent necessity it is better to have the cistern formed of white

earthenware, or of copper inside a wooden casing. Lead would serve as well as copper, but is usually associated with rougher work.

Position of Cistern.—There are two positions which have become more or less "standardised." In the one the cistern water level is about 7 or 8 feet above the floor, its outlet being about 4 or 5 feet above the seat; in the other (commonly known as the "combination" pattern) the bottom of the cistern is only a few inches above the seat. The former is the more common, and requires less room from front to back, as the cistern projects over the closet. The other is adopted when headroom is limited; but it requires more floor space, as the cistern must be quite behind the closet. The low cistern is fitted with a larger outlet valve to compensate for the lesser head. When properly proportioned its working is quite satisfactory, and the noise is usually less. This is in part due to the fact that while the high cistern is often of cast iron and uncovered, the low cistern is almost invariably enclosed in a wooden cabinet, in the same way as the finer grades of high cisterns.

Supply of Water to Mechanical Closets.—These are only mentioned in view of the fact that valve closets are not necessarily to be condemned; most of the arrangements are obsolete. One of them—a cistern with ball-cock forming part of the closet—has already been described (p. 110). It usually formed part of a plunger closet, but valve closets have been made with the same arrangement.

The other methods are: A valve at the closet itself actuated by the closet handle, and a valve in a cistern actuated by a wire. With the pan closet these were quite simple, as there was no need for much water to run after the handle was released. But with the valve closet it is necessary that a quantity of water should run after the valve is closed, in order that the basin may be filled in readiness for the next use—the water already stored in the basin being, as already explained, the chief agent in clearing the closet. If, therefore, the shutting

of the closet valve and the supply valve were simultaneous this would not be the case. The two contrivances adapted to secure the "after-flush" were the "bellows regulator" or other equivalent in the case of the valve at the closet, and the "service box" in the case of the cistern valve. The regulator need not be described further than to say that while the lever of the supply valve was raised by the pull of the closet handle,

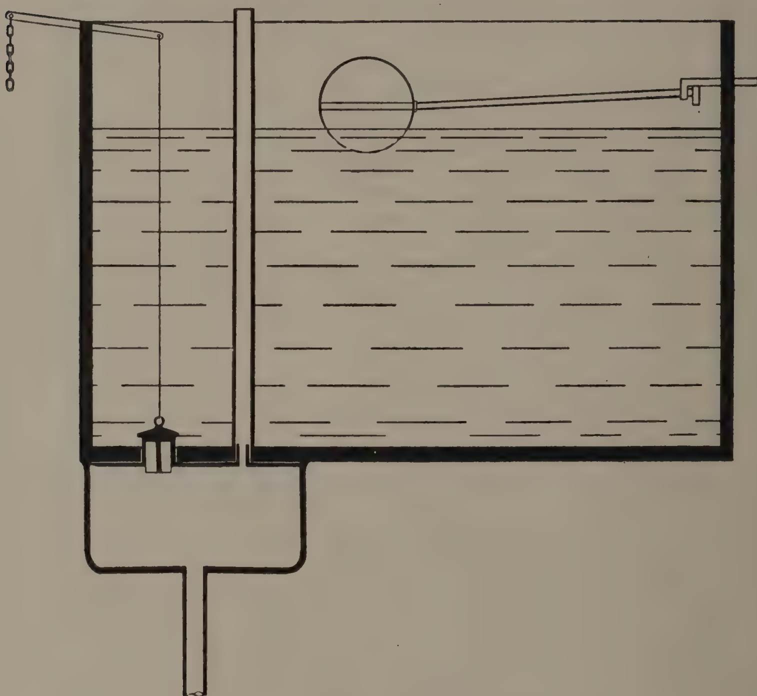

FIG. 52.—Cistern with Service Box.

so that the outlet valve and the supply valve were opened simultaneously, the release of the handle (which closed the outlet valve) only *allowed* the supply valve to begin to close. The closing was retarded by a bellows arrangement from which the air had to escape as the closing took place, and this escape could be regulated so that the basin was filled to the proper level by the time the valve was completely closed.

Fig. 52 illustrates the other method. The raising of the

handle opens simultaneously the closet valve and the cistern valve. Immediately under the latter is the "service box," and this fills immediately the valve is opened, and remains full while the water is running. When the lowering of the handle closes both valves the water in the service box runs down and fills the basin to a height determined by the size of the box. The service box is fitted with an air pipe, otherwise the fall of the water would be checked, and might cause the collapse of its sides. From a sanitary point of view this arrangement is quite satisfactory, but it gives no check on the use of water, and can only be used where the supply is unrestricted. The cistern is much larger than an ordinary flushing cistern, but should be used for nothing but closet flushing; one cistern, however, may serve for several closets. Self closing valves in the cistern are also used, but are more complicated and less certain. The water supply should be unrestricted if the best results are to be got from a valve closet.

Flushing or "Service" Pipes.—From the small cistern of the waste preventing type the usual size of pipe is $1\frac{1}{4}$ inches, assuming that the height of cistern is about the average and that the pipe is fairly straight. A smaller size is not so effective, a larger is apt to cause splashing. Any unusual conditions, such as bends or lessened height, are met by using a larger pipe, while greater height might require a smaller one. The last, however, is not desirable, for the greater velocity does not compensate for the restricted volume.

From the low-set cistern of the "Combination" type there is practically no pipe, but a tapering mouthpiece connects the outgo of the cistern—which may be about 3 inches in diameter—with the closet basin.

For valve closets the size of flush pipe is of less importance, all that is needed being a wash of water to rinse the basin. A 1-inch pipe is usually satisfactory, but the valve should be considerably larger, say $1\frac{1}{2}$ or 2 inches.

Automatic Flushing.—This is seldom adopted except in public

or semi-public places, where there is a probability that the operation may be neglected by the users. There is no difficulty in providing for these conditions by having the seat movable through a short distance (pivoted at the back) and so connected with the cistern that its depression and subsequent release start the syphon. The seat is depressed while in use and raised by a spring or counterweight. An alternative method of automatic flushing is to have the mechanism connected with the door. It is only in exceptional circumstances that such automatic methods should be used; it is not desirable to assume that users are unacquainted with the elements of sanitary requirements.

"**Dry Cisterns.**"—Cisterns have recently been introduced which normally stand empty, and which are only filled immediately before being discharged. The object is to avoid damage by frost.

CHAPTER XV

URINALS

The general use of non-mechanical closets has led to the practical abandonment of urinals in private houses. It has long been recognised that a urinal was inevitably offensive, but in the days of boxed-in closets there was really only a choice of two equally unsatisfactory arrangements, and urinals were frequently installed.

The non-mechanical closet, with no woodwork other than a hinged seat, meets the difficulty fairly well. It is not free from objection, particularly on the ground that its height is insufficient to ensure cleanly use, and that its consumption of water is rather extravagant; but even when these are taken into account it is much better for private houses than any urinal which has ever been devised. The type of closet is so customary that the lifting of the seat is familiar to almost everyone, but for closets which will be frequently used as urinals the seat is sometimes counterweighted so that it retains normally a vertical position.

For public or semi-public places the case is different, and at railway stations, hotels, clubs, and the like special provision is always made. The trough and basin urinals, which were at one time very common, have now been superseded by the "stall" type, and the deep rectangular recesses which used to be provided for the users have given place to the slightly concave spaces. A typical arrangement is shown in Fig. 53. It is seldom that one stall only is required. Each stall is made of one piece of ware, and in a range of urinals covering pieces are provided for the junctions. By this means there is no broken or rough surface exposed to pollution, and the flushing is easy and effective. School fittings are discussed elsewhere (see p. 190). The shallowness of the recess does much to ensure

that no pollution of the floor surface will take place at any distance back: and the surface close to the urinals is made

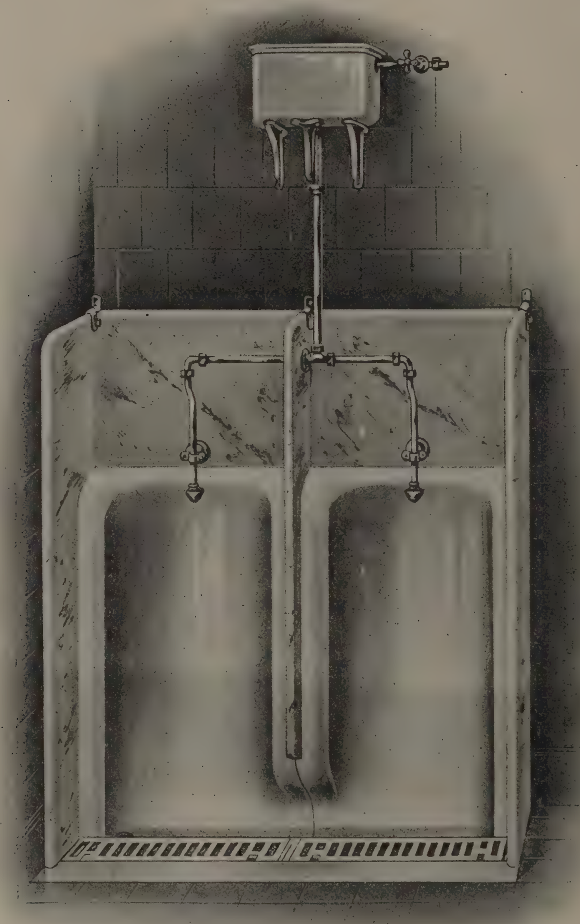

FIG. 53.—Urinal. (By permission of Messrs. Doulton & Co.)

with a slight slope to the channel which runs along the front, very often partly under the surface. By this system the

only part exposed to pollution which is not regularly flushed is the sloping floor in front of the channel, and this of course should share in the ordinary floor scrubbing. If it is made in non-absorbent material there is no reason why it should become offensive. The points which are kept in view in designing these fittings are that the surface exposed to pollution should be free from any angles or recesses, that the whole material should be impervious, and that every polluted part should be effectively cleaned.

The channel may either be covered with a grating, as in Fig. 53, or recessed as shown in section in Fig. 54. It should connect with the drain through a trap, and the connection should not be into any waste pipe, but into the main drain or soil pipe. A pipe from a urinal should be treated in every respect as if it were a soil pipe.

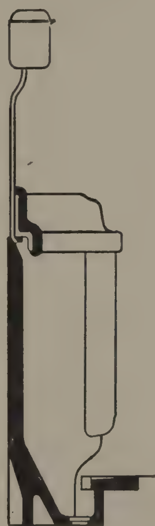

Fig. 54.—Urinal in Section.

Flushing.—This should be automatic and should in no way depend on the use of the urinal. The system by which a treadle, moved by the weight of the user, turned on the water is entirely obsolete. In practice it was found that the treadle mechanism, which was necessarily under the floor, was almost certain to become foul; and syphon cisterns are invariably used instead. These cisterns are of a capacity proportioned to the number of stalls to be flushed (for the sake of appearance they are often made of glass), and a convenient and reliable method is to branch the pipes off as shown in Fig. 55. The pipes are of graduated sizes, and the distribution is more effective than if a number of stalls are fed from one pipe. It is not desirable to flush more than eight from one cistern, and one gallon per stall is a common allowance. The frequency of the flush depends on the rapidity of feed to the cistern, and this is controlled by a stop-cock, and should have some relation to the numbers using the apparatus. In places

where the use is confined to a short period—theatres, halls and the like—the water is at other times shut off.

Spacing of Stalls.—For adult use, 2 feet from centre to centre is the usual spacing. They are sometimes made 2 inches less, but the wider size is preferable.

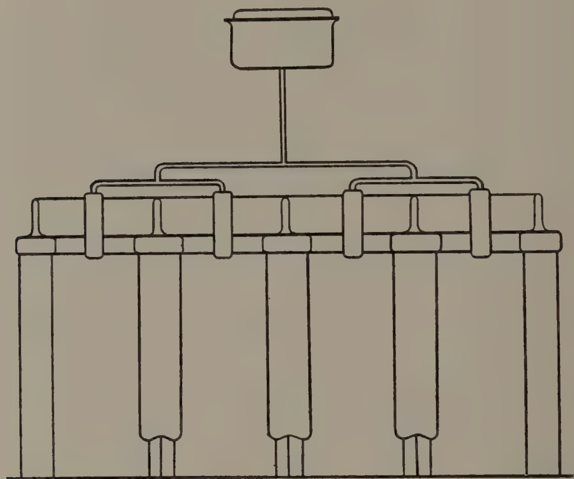

Fig. 55.—Urinal, showing Distribution of Flushing Water.

Material.—Earthenware or fireclay, with enamelled surface, is most suitable. The surfaces exposed to pollution are best to be white, though for the sake of cheapness yellow glaze is sometimes adopted: while the pieces which cover the joints are usually white, but for ornamental considerations are sometimes made of some dark marble colour. Iron is not a suitable material. For cheaper forms, slabs of oiled slate are sometimes employed; while in one public institution with which the author had to do it was necessary (for the convenience of invalids) to have a flat wall surface, and plate glass was used to cover it, with satisfactory results.

CHAPTER XVI

BATHS

THE bath which is usually found in an ordinary house is of the "plunge" or so-called "slipper" type. This is a receptacle which is partly filled with water, and which is large enough for the user to lie with all his body submerged except the head. The following may be taken as ordinary dimensions and shape, though in different kinds of bath considerable variations are found.

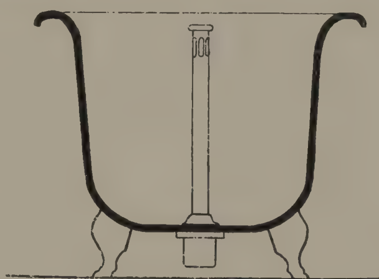

FIG. 56.—Cross Section of Bath.

The depth measured inside is about 20 or 22 inches, and the greatest width about 24 or 26 inches. The greatest width is at the top, as the sides converge slightly to meet the bottom

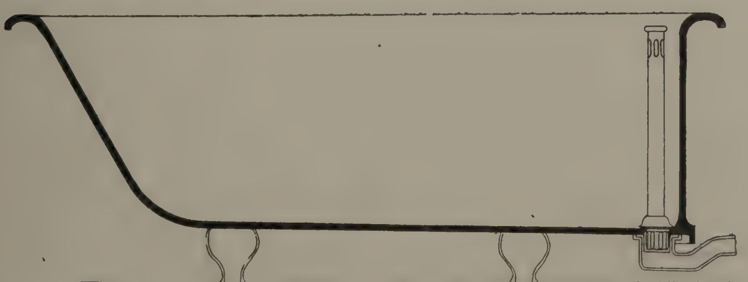

FIG. 57.—Longitudinal Section of Bath.

(Fig. 56). In a "parallel-sided" bath the width remains the same from end to end, while in a "taper-sided" bath the width is less at the end intended for the feet of the user. The

head end of the bath is usually sloped at a considerable angle, (Fig. 57) so that the length on the floor of the bath is considerably less than the length along the top, which is from 5 to 6 feet. The term "slipper" bath is supposed to have originated at a time when the bath was covered over at the foot end; it is in no way descriptive of the bath as now constructed and might well be abandoned. To fill such a bath ready for use will require anything up to 50 or 60 gallons of water.

Such a bath implies (1) that water is led to it by pipes controlled by taps; and (2) that the bath can be emptied at pleasure by removing or raising a plug. This introduces the further requirement of an overflow arrangement, so that if the taps are by accident left running while the plug is closed, or if by any other means the water level rises too high, the surplus water is carried harmlessly to the drain.

There are two points of special sanitary importance—the material of which the bath is made, and the arrangements for disposing of the water which has been used.

Material.—Wood, zinc, and lead may be dismissed without further remark. They are entirely unsuitable and out of date.

Copper is in some respects very suitable. It is light, pleasant in use, does not absorb much heat from the water, and is easily kept clean. But unless it is made of such thickness that the difficulty of construction is considerable, and the cost excessive, it requires some outside support. This introduces the wooden cradle and the objectionable system of wood boxing, so that in spite of its intrinsic advantages copper is now scarcely regarded as a practicable material.

Marble has been often used. When a bath is hewn from the solid block the only serious objection is the cost, but this is sufficient to make such a bath impossible for any ordinary purpose. No other material can compare with it in appearance. But when marble is used in the form of slabs the result is unsatisfactory. It forms numerous sharp angles which are difficult to keep clean; it is not easy to make the

joints tight, and still less so to keep them tight; and sooner or later leakage becomes chronic.

Porcelain or white enamelled fireclay is the best available material when weight and absorption of heat are not serious objections. Either has a surface which is practically indestructible except by actual violence, and which is very easily kept clean. For institutions of any kind, where numerous baths may be wanted in quick succession, this type of bath is used almost as a matter of course, and in spite its somewhat high cost it is ultimately economical. Its disadvantages are its great weight—a full-sized bath may weigh 8 or 10 cwts.—and the fact that this mass of material has to be heated at the expense of the heat in the water. It is therefore not very suitable where hot water is limited, or where the bath has to be carried on a light structure.

The high cost of such baths is due chiefly to the fact that a large proportion come out of the kiln with flaws or blemishes. A very slight blemish makes the bath unsaleable as "perfect," although its soundness and serviceable qualities may be unaffected. Such baths have therefore to be sold at a cheap rate, and it is often possible for one who can select from a stock of "seconds" to get an excellent bath at a low price on account of some scarcely noticeable blemish—this being almost the only instance in sanitary work where it may pay to use anything but the best material. The loss thus incurred by the makers has to be made up by the profit on the "perfect" specimens.

Coating.—Cast iron, which is now the most popular material for baths, depends for its success altogether on its protective coating. Unprotected iron would be quite unsuitable: a coating of ordinary paint is little better. The castings are, therefore, covered, on the inside at least, with "enamel," of which there are three leading varieties:—

Metallic enamel is not much more than a superior variety of paint, the article enamelled being heated in a stove after the coating has been laid on. The colour is almost always "marble," but it does not last long. This enamel is popular

with those who build houses for sale, but it should never be used for good work.

Vitreous and *Porcelain* enamel are fused on to the iron, and to a certain extent become incorporated with its surface. The former is practically the same as the "glass" enamel of pipes, mixed with some pigment which converts the semi-transparent yellow substance into an opaque skin of some light colour. The latter is made of porcelain material, and has the opaque whiteness of that substance instead of the modified transparency of the glass. Its appearance is on the whole somewhat better, but otherwise there is little to choose between them. When well made either coating is quite reliable, it will not peel off, nor will it separate from the iron under the influence of expansion and contraction. The surface is non-absorbent and easily kept clean. It is however in itself somewhat brittle and fragile, and although the backing of iron gives ample strength to the bath as a whole the coating may easily be chipped or splintered by a sharp blow. With reasonable care this should not be possible, and this type of bath is almost universally used when a good article of moderate weight and at a moderate price is required.

The enamel coating may be applied outside as well as inside, but as the outside has no wear and tear to withstand there is no objection to the use of ordinary paint, and very often it is painted to harmonise with the other decorative work in the room.

Shape.—The general shape has already been considered. It must further be noted that the bath should have no sharp angles, and that its appearance should be such as to require no covering of any description. In particular, the top edge must finish with a "roll," solid in the case of porcelain or similar baths, but hollow in the case of cast iron (see Figs. 56 and 57). The bath is usually set on feet, but of late there has been a tendency—of very doubtful advantage from the sanitary point of view—to form a plinth or base all round. If this is filled with cement, as it may be when used on some kinds of floor, it is quite right, but it is not desirable that any

such space should be left empty and inaccessible. Except in the above respects the shape of the bath is a matter of individual choice, and does not concern the engineer.

Inlet for Water.—It was at one time the custom to introduce the fresh water through the same opening in the bottom of the bath which allowed the used water to escape. This was effected by connecting the feed pipes (not shown) into the "rod-pipe" A in Fig. 58. The object was, among other things, to prevent the escape of steam into the apartment, which takes place with considerable freedom when hot water is allowed to enter from a tap over the top edge. This method allowed dirty water to be washed back into the bath, while if the feed and waste valves were opened simultaneously, great and unobserved waste of water might take place. The system is now obsolete. A later plan, with the same object in view, was the introduction of the water through the end of the bath at about one-third of its height, the one inlet serving for hot and cold water, which were thus mixed before entry. This also has been given up, because it introduced the risk of dirty water being sucked back into the pipes (compare the example given on p. 236); and the usual practice now is to have the inlet above the level at which water may stand in the bath.

The size of inlet is of some consequence from the point of view of convenience, as small inlet pipes cause very slow filling. Each tap should be at least an inch in diameter, unless the pressure of the cold water is very great, and in public institutions where the inmates have to be bathed in succession, it is usual to have $1\frac{1}{2}$-inch, or even larger, taps. Of course the supply pipes must be properly proportioned, as it is no advantage to have large taps if the water cannot reach them freely. From considerations of safety from flooding, the inlet taps must be governed by the available discharging capacity, and this limits their size in ordinary houses.

Outlet and Overflow Pipes.—These may be separate or in combination, but both are essential, except when the bath stands in a place where no harm would result from a flood.

The overflow pipe is needed to take away water which may be allowed to enter by careless use of the filling taps, or which may be displaced by the user entering the bath when it is already full. In the former case the overflow may be continuous, and the amount is limited only by the delivering capacity of the inlet pipes. In the latter case the overflow is only for a few moments, but during this time as much as twenty gallons of water might be displaced. This is largely met by the provision of sufficient "freeboard," and the general

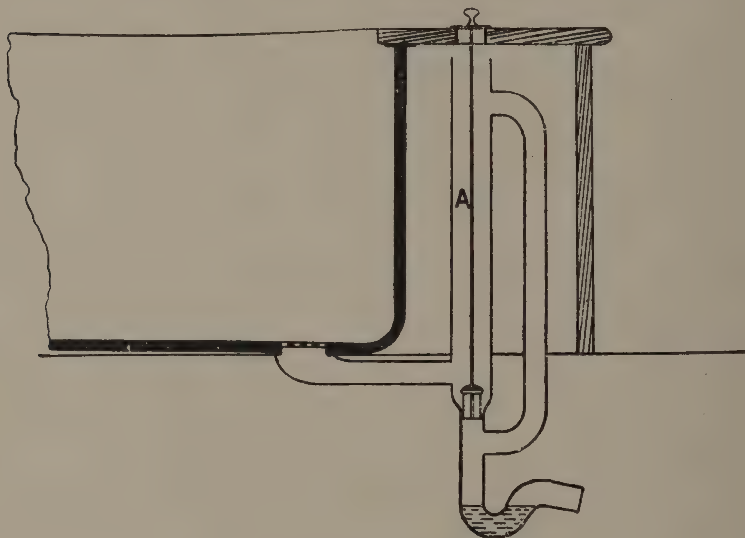

Fig. 58.—Bath with Concealed Overflow.

design of the bath should be such that the space between the level of the overflow and the top edge will contain as much water as may be thus displaced. Two precautions, independent of each other, should be taken:—The overflow pipe should be of sufficient size to take away all the water that may come in, while the capacity of the bath above the overflow level should be sufficient for displacement.

The important matter from a sanitary point of view is to have the overflow so arranged that it will not become foul. The old arrangement of concealed overflow (Fig. 58) was an

excellent example of how such provision should not be made. The overflow was entirely inaccessible for cleaning, and it was only by chance that any flow of water took place through it. The plug itself was so placed that the services of a plumber were required if anything went wrong with it; and as a consequence it was never seen or disturbed except when it became so dirty that it failed to hold water, or got tilted, as it sometimes did, out of its place.

Of the types at present available, the movable hollow plug is undoubtedly the best. It is usually placed in a recess at the bottom of the bath, and is so fixed that it can readily be withdrawn for cleaning. The arrangement is shown in Figs. 56 and 57. In ordinary use the plug is in the position shown, closing the outlet of the bath. If the water rises too high it escapes through the pipe of which the plug is formed. To empty the bath the plug is raised slightly from its seat, while for cleaning it can be entirely removed. There is thus no part which is not readily accessible. There are various modifications of this general type—in one the plug is depressed instead of being raised to allow the water to escape, and in another there is a cap on the top, by which a syphon action is started when the water level is sufficiently high. The main point in every case is to have no part which cannot be cleaned, or which is so concealed that the need of cleaning may be overlooked. The plug is to some extent an obstruction which may be minimised by forming a recess in the end of the bath to receive it (Fig. 59).

Fig. 59.—Recess in End of Bath.

It is only necessary to mention the glaring mistakes which are sometimes made in overflow connections, by connecting the overflow pipe to the waste pipe beyond the trap. Such mistakes are occasionally, but rarely, found.

Safe Trays.—When built-up baths were in use, safe trays were an indispensable part of the installation. The joints of the bath might readily crack and leak; and it was necessary to protect the floor, and possibly the ceilings beneath, from the result of such an accident. The mechanical closets were provided with similar trays, partly to deal with the leakage from valves and journals and partly to deal with unobserved overflow. The same applied to baths with wooden casing.

These trays were formed of sheet lead, forming a sort of carpet over the concealed part of the floor. The water which they collected was supposed to be carried off by a safe pipe, which in the older times was connected (sometimes without a trap) to the soil pipe, but which in later times was discharged through the wall into the open air. In the one case there was considerable danger of foul gases coming up these pipes, or even of foul water being splashed back; in the other the current of cold air which blew in added considerably to the risk of frozen pipes. Flap valves on the outer end were not a satisfactory protection: they might break off or freeze tight. With the modern style of fittings, in which jointed construction is unknown, and where every part is freely visible, safe trays are seldom needed. Accidental splashing is dealt with in the same way as it would be dealt with in any other part of the house—that is, it has to be mopped up instead of having any channel provided for it. Of course there are cases in which sanitary fittings are so placed that any leakage of water would be a serious matter, and provision is made to prevent this reaching, perhaps, an elaborate ceiling below; but this is rather a structural than a sanitary requirement.

Small Baths.—The smaller class of baths, such as sitz baths, foot baths, children's baths, and the like should be considered on exactly the same principles. The material, construction, mode of supply and removal of water are not affected by the change of size; and the general rule against the introduction of any part which cannot be cleaned as part of the ordinary household work should apply.

Spray and Shower Baths.—The spray or "needle" bath in which the user stands in the middle of a large number of converging jets of water each delivered through a small orifice (Fig. 60) has come into prominence in recent years, chiefly in

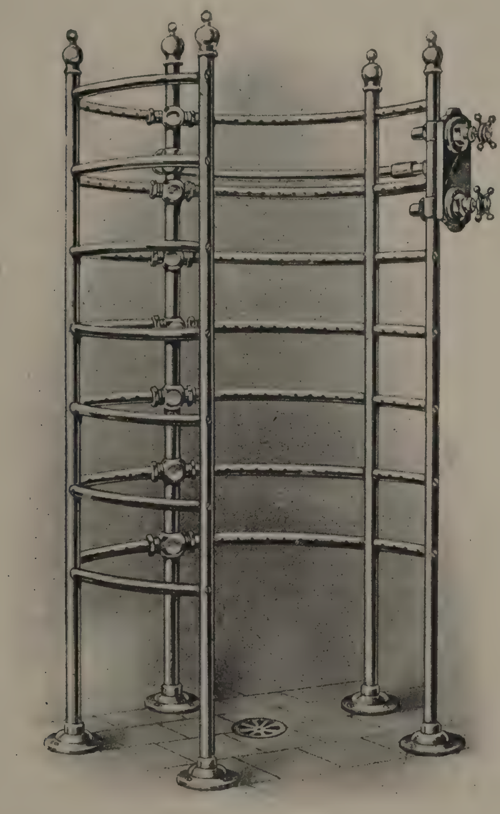

FIG. 60.—Spray Bath. (By permission of Messrs. Shanks & Co.)

connection with schools and institutions, and as an adjunct to swimming baths. It is frequently fitted in private houses, but there it is usually placed over the end of a plunge bath and forms part of the same construction. The American method of having the spray bath quite apart from the plunge bath has a good

deal in its favour, and where only one can be fitted a good case might be made for the retention of the spray (with or without shower) and the abolition of the plunge. Where the bath is regarded as a therapeutic agent or as a luxury, it may be of importance to have the possibility of immersing the body in water of any desired temperature; but where it is to be used solely for purposes of cleanliness the spray bath has many advantages.

The "shower" is delivered from a perforated disc under which the user stands, so that the water falls on the head and shoulders. The apparatus is simpler and cheaper, though scarcely so effective as the spray; with which, however, it is sometimes combined.

A spray of a kind may be made by fixing a hose pipe with a "rose" attached to the supply tap of a plunge bath. This is scarcely a satisfactory makeshift.

Advantages of Spray.—(1) *Economy of Water.* The body can be effectively cleansed with ten gallons, or less. The water is required (1) to wet the skin thoroughly, and (2) to wash off the soap. Between the wetting and the wash down the bather has a thorough soap bath, and the second operation consists merely in a liberal "sluicing" to remove the lather. A plunge bath of very moderate size will hold 50 gallons of water.

(2) *Greater Cleanliness.* In a plunge bath, when a thorough wash is required, the bather is ultimately immersed in water which is far from clean. In rising from it the skin is coated with the scum which has formed on the surface, and unless this can be washed off the result is unpleasant. With a spray bath, on the other hand, the whole bath is taken in running water, and the unpleasant products are promptly washed away. Further, while in the plunge the bath itself is coated with dirty water, and requires frequent cleaning, any part which is wetted during a spray bath (except the small basin) is splashed with clean water.

(3) *Economy of Space.* Instead of the 7 feet by 2 or 3 feet which would be required for a plunge bath, a space of about 3 feet square is ample for a spray. Including dressing space

and space for clothes, towels, etc.,—that is, the entire bath-room—a space of $5\frac{1}{2}$ by 3 feet may be made to serve (see Fig. 61).

An indirect advantage of no small importance is that the abolition of plunge baths in a certain class of houses would merely abolish a place where coals, firewood, and other sundries are frequently stored. If the bath space is to be abused in this way, the less that is provided the better.

The spray bath requires no overflow, as there is no plug, and no receptacle to be filled with water. There is simply a floor or tray with a gentle slope to a trapped outlet, and a metal or rubber curtain to prevent the water from splashing too far.

Whether or not this bath should supersede the plunge bath in private houses, there is little doubt that it should do so to a great extent for public or semi-public use. If a number of such baths are used together, as for instance in a school, the whole floor and wall space is made impervious, and the arrangements become extremely simple. Where the purpose is to enable those who have no baths in their houses to have a thorough wash, spray baths can be fitted up and maintained at a cost much less than would be entailed by a similar number of plunge baths; and this may make all the difference between ability and inability on the part of a local authority to carry on such an establishment. As an adjunct to swimming baths, it is an elementary rule in well-conducted establishments that the person who is about to use the swimming bath has a preliminary wash down with soap in the spray bath; and this, which takes little time and a very moderate allowance of water, is of the utmost importance in retaining the freshness of the swimming pond.

The spray bath is arranged in one or other of two ways: (1) The delivery pipes are of circular form, the circle being incomplete to the extent necessary to allow the user to enter, and are set one above the other as illustrated; or (2) these pipes are straight and vertical, ten or twelve being set round the circumference of the casing. In either case the water is supplied to them through a mixing box, in which the

hot and cold water mix to give a proper temperature. Where the bath is under the control of an attendant a thermometer is usually fixed in the mixing box, so that the temperature may be properly regulated. Otherwise the user has control of the taps which govern the supply of hot and cold water, and can adjust the temperature to his own comfort. Where public baths are frequented by children considerable care must be exercised, or the "hot spray" will be used to an extent which may be injurious.

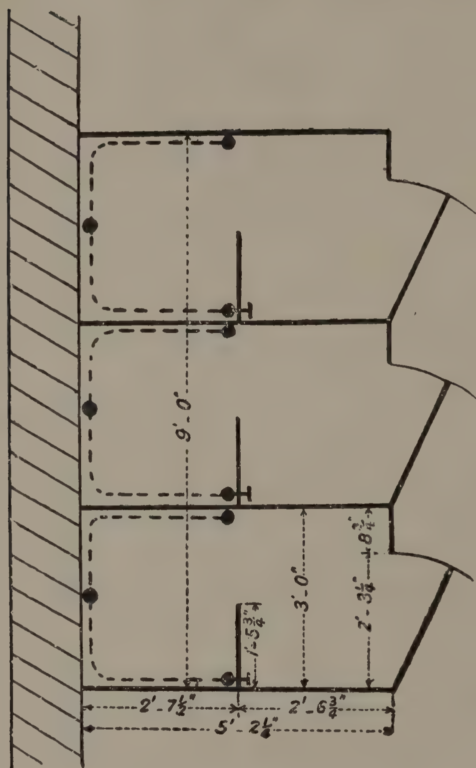

FIG. 61.—Set of Spray Baths for Works.

The question of providing baths at the pits or works for miners and others whose occupation involves exposure to dirt is now much before the public, and it is by the provision of spray baths that this requirement can be best met. Fig. 61 shows in plan a set of three baths provided for a brass foundry. The partitions are of enamelled iron; the user has control of both hot and cold water, the taps being readily reached either from the outer or the inner compartment; and the granolithic floor slopes to a grated outlet in the centre of the spray.

CHAPTER XVII

LAVATORY BASINS

The lavatory basin has passed through an evolution very similar to that of baths, the concealment of all pipes and connections having been replaced by complete visibility. The general principles of sanitary design, and to a great extent their application, are the same in basins as in baths.

Material.—Earthenware in its various forms is almost universal. For places where rough usage is probable white enamelled fireclay is used, the basins in this material being thick and massive; while for ordinary household equipment lighter and thinner material is adopted. Where extremely rough treatment is to be met, enamelled cast iron is sometimes used, but this, though common in America for even fine work, is not much favoured in Britain.

For clubs, hotels, and the like, where ranges of basins are required, the basin and the top may be separate and of different materials. The same arrangement is often adopted in private houses where a handsome appearance is desired. In these cases the basin is of earthenware, but the top is of marble—the upper edge of the basin or basins and the underside of the marble being ground to make as tight a joint as possible. But even with the greatest care the joint is not so impervious as the continuous material, and the absence of any joint is a distinct advantage as regards cleanliness.

As against this, the basin separate from the top has the advantage that if it is accidentally broken it can be replaced at less cost than if the two were in one. But if a basin of other than the commonest type is broken after a few years' use it may be that no similar basin can be readily got, and it may take months to have one especially made. Altogether, the

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advantages are entirely in favour of basin and top in one piece, and when greater richness of appearance is combined with less sanitary efficiency it is suggestive of ostentation rather than refinement.

Water Supply.—The bottom feed is objectionable for the same reason as in baths, and is obsolete. The usual method of supply is now by means of two independent taps projecting over the side of the basin. There is, however, a decided convenience in having the hot and cold water introduced by one

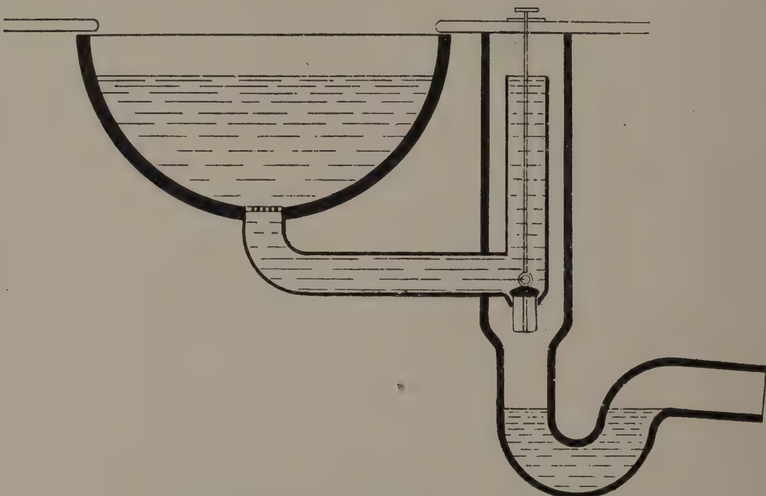

Fig. 62.—Basin with Concealed Overflow.

inlet, as it is then possible to have a flow of water at any desired temperature. In this way one may wash in running water, and though the saving in water by this method is not so marked as in the case of baths, the greater cleanliness is obvious. The objection to this—that it makes a connection between the hot and the cold water pipes—is easily avoided by making the outlet to the basin of liberal size as compared with the taps.

Outlet and Overflow.—The single outlet in the bottom of the basin, with the stand pipe behind forming a concealed overflow

(Fig. 62) is illustrated only to be condemned. It is convenient from the point of view of the amateur photographer, as it is more suitable for photographic washing than the more modern types, but it has little else in its favour. It presents a large fouling surface, which is inaccessible for any ordinary cleaning, and any obstruction requires a tradesman to remove it. Equally bad on the whole—worse in some respects though better in others—are the basins where the overflow is part of the ware, entered by a series of holes near the top of the basin and joining the discharge pipe below the plug, and with no

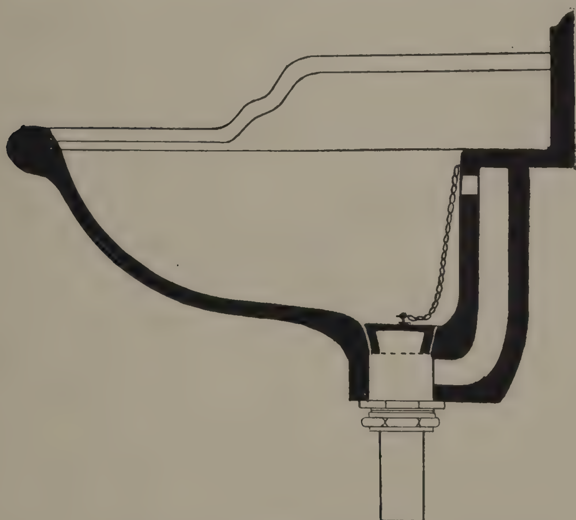

FIG. 63.—Basin with Overflow formed in the Ware.

means of access (Fig. 63). When the top is left open for cleaning this type is not so bad, but unless the overflow is made so conspicuous that it will certainly be cleaned regularly, it is not a very sanitary appliance. This type of overflow has become very common of late years in basins fitted with a rubber plug and chain. The apparent simplicity of this arrangement is deceptive, and the existence of the unsavoury overflow is often forgotten.

The visible overflow arrangements which have been devised are very numerous, but there are two main types under which

nearly all may be grouped. The one is the tubular plug, the other is the weir.

The **Tubular Plug** is illustrated in Fig. 64, and is precisely similar to that used for baths. In order to give room for this arrangement without interfering with the use of the basin, it is usual to make the inside of the basin of some such shape as is shown in plan in Fig. 65. The basin in this illustra-

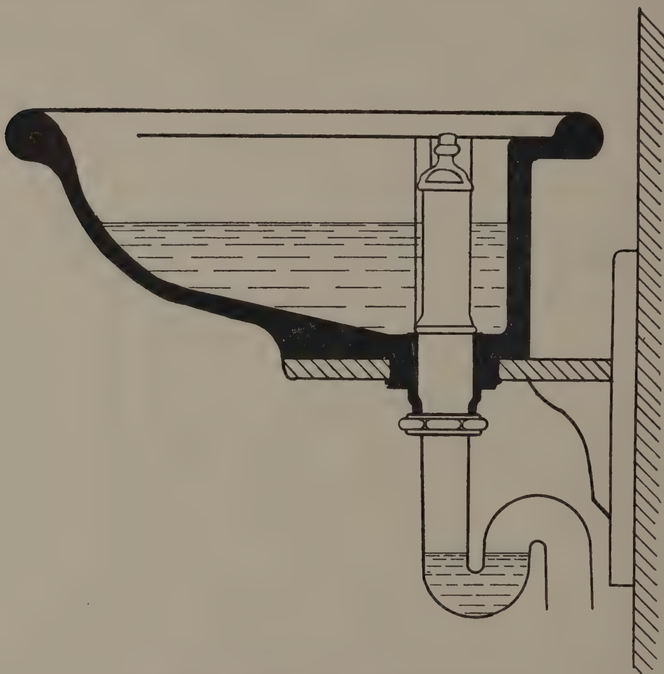

Fig. 64.—Basin with Tubular Overflow.

tion stands clear of the wall, supported on a pedestal or a bracket, but the same inside shape can be adopted with a straight back outside.

The **Weir** overflow is shown in Fig. 66. The plug closes the passage from the bottom of the basin, and when lifted allows the water to flow direct into the trap; but if water continues to enter the basin when the plug is in position it runs over the weir and escapes through the hollow plug.

Either of these meets sanitary requirements fairly well. The tubular plug exposes less surface to pollution, but on the other hand, the weir and the space behind are more easily got at for cleaning. It is, of course, important that the tubular plug in the one case and the short plug behind the weir in the other should be easily removed.

Tip-up Basins.—These are never desirable fittings, as the outside of the basin and the inside of the receiver are always

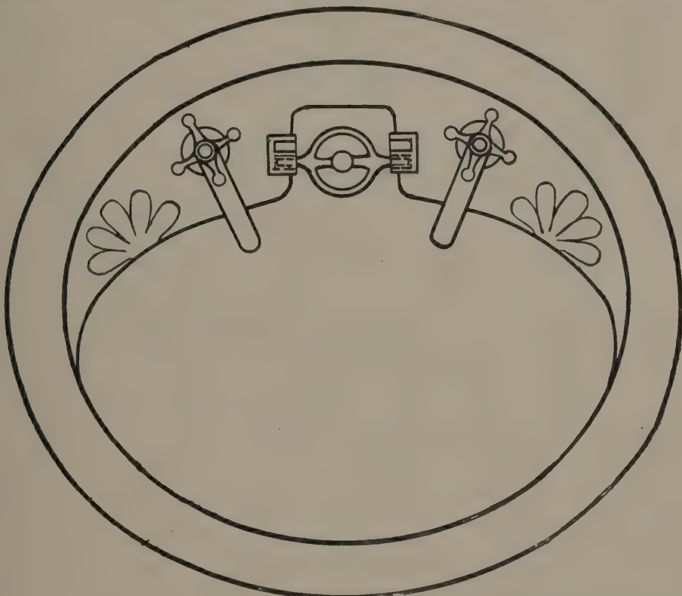

Fig. 65.—Plan of Basin with Tubular Overflow.

fouled. They are popular because it is possible to empty them quickly, and are chiefly used in hotels and clubs. Even there, where it may be assumed that they will be taken out and cleaned daily, the dirtiness of the surface goes on increasing in the intervals between the times of cleaning, and basins with less fouling surface are generally preferred.

General Shape.—When the outlet was in the bottom of the basin and the plug entirely outside, the shape was naturally

circular or oval in plan. The outlet was in either case in the centre. Modern basins are made to drain to an outlet at the back, often recessed, as shown in Fig. 65, and the general shape is either oval, or rectangular with rounded corners. Basins are also made to fit into corners, the shape being modified accordingly. In any case, it is made so that it can be conveniently supported on a bracket or pedestal. The recesses for soap and brushes, which in the old basins became receptacles for dirty water, and were always provided with covers, are now merely shallow depressions with ribs to support their contents; and they are so made that they drain freely into the basin (Fig. 65).

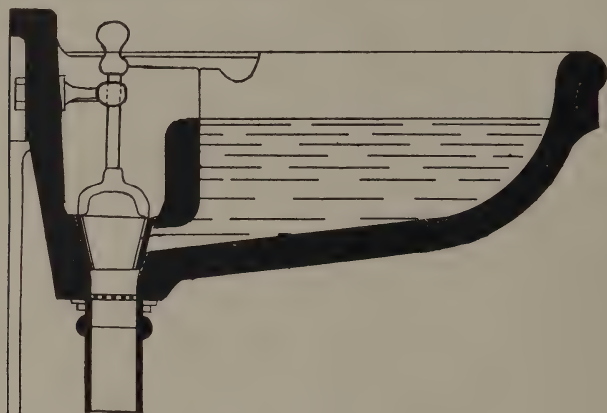

Fig. 66.—Basin with Weir Overflow.
(By permission of Messrs. Shanks & Co.)

Basin Ranges.—These may be continuous or separate. The basins in a continuous range have the top slab like a table, in which the basins are set, the front being straight or with curves to follow the outline of the basins. If the slab is in one piece with the basins, overlap joints occur between each pair of basins. The independent basins, on the other hand, are merely a set of ordinary basins placed closely together, the parts near the wall being in contact. There is little to choose between these from a sanitary point of view, and the choice is largely one of convenience and appearance with reference to the use to be made of the range.

In some basin ranges it is not necessary to provide an overflow from each individual basin, the floor being of such a nature that it will collect and carry off any overflow without injury. In other cases the outlet and overflow arrangement of each basin should be similar to what would be required for a basin standing by itself.

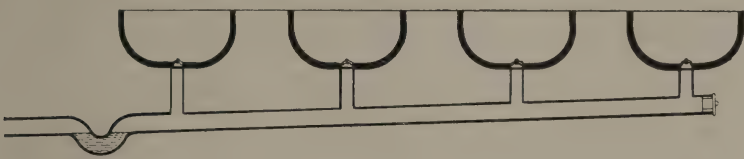

Fig. 67.—Basin Range with One Trap.

Trapping of Basin Ranges.—Each basin should have its own trap, connected to a main outlet pipe, and this outlet pipe should be properly ventilated. A common, but dirty, plan is to make one trap serve for the whole range (Fig. 67); the result is that there is a considerable length of dirty pipe in direct connection with the air of the apartment and quite

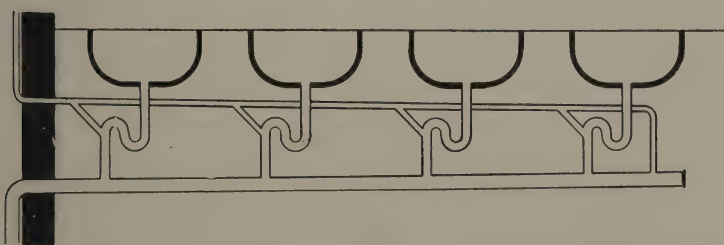

Fig. 68.—Basin Range with Dead End on Outlet Pipe.

inaccessible for ordinary cleaning. Another method is to have an untrapped down pipe from each basin, delivering over an open channel in the floor. This is a sloppy arrangement. Although the channel is accessible for cleaning, the inside of the various down pipes is not, and the wet surface of pipes and channel adds needlessly to the pollution of the air.

When various basins are connected with one outlet pipe, care should be taken to leave no dead ends. Fig. 68 shows an arrangement which is sometimes recommended for the double purpose of providing ventilation and access. It will be seen that the dirty water from the basins will splash back into the part of the pipe which is beyond the highest connection, and that the pipe is thus dirtied without any cleansing flow passing through it. The desired result would be obtained equally well by the arrangement shown in Fig. 69 (with a trap screw at the right-hand end also if required), where there is no part dirtied except what is also washed.

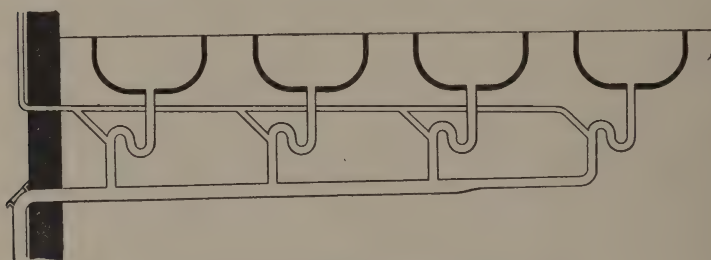

Fig. 69.—Basin Range, Dead End Avoided.

Traps for Individual Basins.—When the pipes were all concealed behind woodwork the traps were of lead. There was, of course, the ordinary risk of bad workmanship, by which a trap might be pulled out of shape or otherwise rendered ineffective ; but the material was as smooth inside as it was outside, and there were no snags or projections to catch dirt. In the open type of basin the lead trap is liable to accidental injury, and in appearance it is not so good as brass or silver. Accordingly, it is customary to make the traps of modern basins of brass (polished or plated) or of white metal. The inside may not get the same care from the makers that the outside does, and may be left extremely rough. The result is that the trap becomes very dirty, and if to this is added that its shape is sometimes determined by æsthetic rather than by sanitary considerations, the polished brass or silver surface may conceal a very undesirable interior. This should be carefully looked to before the trap is put in. The brass trap

and down pipe are practically free from the risk of accidental injury, and are desirable both on that ground and on that of appearance.

One Trap for Basin and Bath.—This is at best open to the objection of having a long, dirty pipe above the trap. If the basin discharges into the bath, a plan which is sometimes adopted, the fouling is much increased.

CHAPTER XVIII

SINKS, TUBS, ETC.

This class of sanitary fittings (other than slop sinks, for which see p. 160) has for its purpose the supply and occasional retention of a quantity of water in which utensils or clothing may be washed. There must therefore be in connection with the receptacle an outlet which may be shut or opened (with or without an overflow arrangement), and a supply of water, usually both hot and cold.

Varieties.—In the smallest class of house one sink has to serve for every purpose, including sometimes that of a wash-tub. In larger houses, however, different sinks are provided for different purposes, the most important being the following:

Scullery.—Used for washing cooking utensils and dishes. The water discharged is therefore heavily loaded with grease, and, as has already been noted, is one of the most troublesome problems in drainage design. In large establishments there is often a further sub-division, one sink being reserved for rough washing and another for final cleansing.

Vegetable Washing.—These sinks have to remove earthy matter, sand, etc. from vegetables. The discharge from them therefore, while not very offensive, is apt to be heavy and readily deposited.

Pantry.—In pantry sinks light and fragile articles are washed, and as these are as a rule only slightly soiled, the water leaves the sink in a comparatively clean flow. There are numerous sub-divisions of pantry sinks, varying more or less—such as the butler's or table-maid's pantry, chiefly for washing glass and silver; flower pantry; etc.

Housemaid's Pantry.—This is of somewhat doubtful class. If it is fitted alongside a slop sink, or if a closet is used as a

slop sink, then the pantry sink is only used for rinsing utensils, and for drawing water. In that case the discharge is not seriously polluted, as the dilution is very great. If on the other hand the sink is used as a receptacle for the actual discharge of slops, then of course it should be treated altogether as a slop sink, and the ordinary type of sink is inapplicable.

Water Supply.—The method of supply is of some importance. It should not be so high as to cause needless splashing, and at the same time it should admit of any vessels that require to be filled being put readily under the taps.

Tubs.—The articles treated are soft and bulky, requiring sometimes prolonged soaking in water of suitable temperature. Considerable capacity is therefore wanted, and the shape and height must be adjusted to suit the conditions of use. The water discharged is decidedly foul, and contains a large quantity of soap; it readily causes offensive deposit in the pipes.

Nursery Sinks.—Strictly speaking, these may come more or less under the category of slop sinks, owing to the washing of soiled garments. On the other hand, these may be sent elsewhere and the nursery sink used merely as a rinsing and draw-off sink. In that case the water discharged should be comparatively clean.

General.—It must always be borne in mind that while a sink or other fitting may be provided for some specific purpose, it cannot be assumed that it will never be used for another and more offensive purpose. This may happen through accident or emergency, through carelessness, or through laziness. Such misuse, if habitual, implies as a rule serious fault on the part of some of the occupants, though the blame may in some cases more justly be attached to the inadequacy of the arrangements. Where, for example, there is one common closet for a number of small houses, each of which is provided with a sink, it is inevitable that the sink will be constantly

misused. For this misuse the occupants cannot reasonably be blamed, but the separation of the system into "soil drains" and "waste drains" is apt in such a case to be very misleading.

Material.—In every case a non-absorbent surface is needed, and fireclay or earthenware has been universally accepted as the best material. The surface is usually white enamelled, though, for the sake of cheapness, yellow or "cane" is sometimes substituted. The outer surface should also be enamelled, so far as it is not set against the wall; that is, the front in every case, and sometimes one or both ends as well. The object of the outside enamelling is to avoid any necessity for boxing with wood. This boxing is unfortunately still common, but it is rapidly falling into disuse. It is sure to be splashed and fouled, and often becomes very offensive. The space under the sink is commonly used for storing brushes, soap, blacking, and such oddments, and objection to the removal of the wooden boxing is often made by those who have been accustomed to the "convenience" of the boxed-in space. Such spaces are merely hiding places for dirt, and it is a great advantage to have them thrown open. The woodwork about sinks is often a stronghold for beetles. more [illegible]

The best arrangement is to have the sink carried on iron standards or brackets, and it is well to have a cross bar for the protection of the trap, otherwise pails, etc. may be banged against it to its considerable damage. In the case of tubs and specially heavy sinks, more massive standards, formed of the same material as the tubs or sinks themselves, may be used with advantage, especially if the floor is of granolithic or similar substance.

In the case of sinks in which fragile articles are to be washed, objection is often taken to the hardness of the fireclay surface, and the consequent damage done. For this reason, sinks for this purpose are sometimes made of wood, or of wood lined with lead or copper. The great objection to any of these is the same, that the wood—whether covered or uncovered—sooner or later becomes saturated with water, and

begins to decay. The metal lining is no advantage in this connection; it may defer the access of the water, but it makes the effect of the wetting more complete by preventing evaporation. It is now generally recognised that the best plan is to have the impervious sink of some material such as fireclay or porcelain ware, and to use a small wooden tub inside the sink for washing fragile articles. This small tub is easily lifted out, and does not remain constantly wet. When it is worn out it is very readily replaced.

Trapping.—A range of tubs is often constructed with only one trap. This is not a good arrangement, as the length of connecting pipe is necessarily in direct communication with the apartment. In the case of public institutions, where there are ranges of considerable length, it may be permissible to allow each tub to discharge into an open channel in the floor, this channel being freely accessible for cleaning. If the water is removed by a closed channel, then that channel should be treated as a drain and made perfectly tight, and each individual fitting should be trapped by a trap as close to it as possible. This applies to both sinks and tubs.

Overflows.—Sinks are commonly made with concealed overflows moulded in the ware (Fig. 70). The overflow water enters by a set of small holes near the top, and is led into the main outlet nozzle just under the grating. Such an overflow is not very effective, as it is very apt to choke, and it is far from sanitary. It is much better to have a large open "weir" overflow, such as illustrated (for a basin) in Fig. 66, or even to have the ordinary overflow constructed with an open top, so that it can be readily cleared if necessary, and cleaned from time to time. Tubs as a rule have no overflows, and sinks might often be fitted without them.

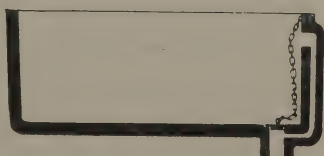

Fig. 70.—Sink with Concealed Overflow.

Slop Sinks.—These are of a totally different class from the other types which have been considered. They are for the express purpose of receiving excretal matters, either from the ordinary utensils in ordinary houses, or from bed pans in the case of hospitals. In most dwelling-houses of moderate size they are scarcely necessary, and in small houses should certainly be avoided. The water closet, other than a valve closet, fulfils the purpose quite well, and there is no object in multiplying fittings. In large houses it is convenient to have such an arrangement quite apart from the closet accommodation, and in hospitals and similar institutions it is essential. It is equally essential, however, that it should be stringently looked after, or it may be very offensive.

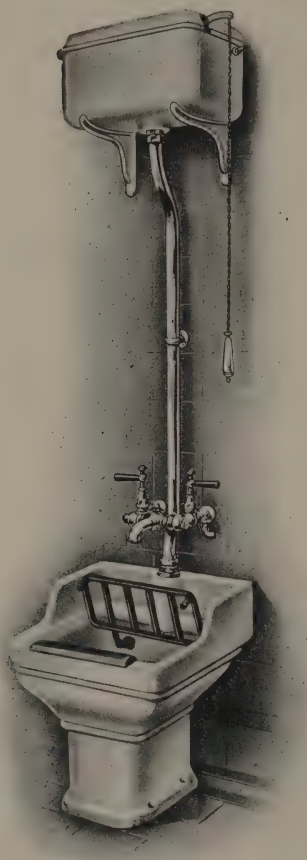

Fig. 71.—Slop Sink. (By permission of Messrs. Shanks & Co., Ltd.)

These sinks are made in many degrees of elaboration, but for the ordinary household nothing is needed beyond a hopper, with a brass grid which can be folded up out of the way or lowered to support the vessel being washed, and a supply of hot and cold water (Fig. 71). In addition to the draw-off taps, the sink should have a supply of water in the form of a flush, similar to that of a closet. The special forms required for hospitals are considered in Chapter XXI.

CHAPTER XIX

TRAP VENTILATION

It has already been seen that a system of drainage must have a free passage for air from one end to the other. The primary purpose of this is to prevent the formation of offensive and dangerous gases, but free ventilation is important for other reasons.

Displacement of Air by Falling Water.—The pipes are used for the passage of volumes of liquid, which may occupy the whole available space, and which in the vertical pipes move with considerable velocity. The air in the pipes is thus violently agitated, and unless it has perfect freedom of movement, it will displace the water in some of the traps. It may do this either by increase or diminution of pressure. Suppose that a system has no openings for the escape or admission of air, as shown for example in Fig. 72. A volume of water discharged through a closet at A would, in descending the pipe, compress the air in front of it, and thus would force air through the traps at B and C. At B, which is the trap of another and lower closet, a quantity of foul air would pass into the house; at C, the "disconnecting trap," it would only be forced through to the sewer, which is of no consequence. At B no doubt the action is only momentary, because as soon

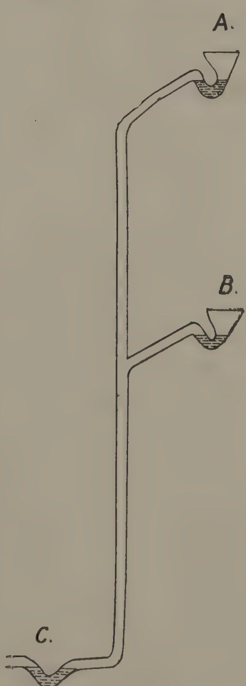

FIG. 72.—Unventilated System.

as the pressure is relieved the water settles back into the trap—except such as may splash over. But that momentary action has driven into the house a quantity of objectionable and possibly dangerous gas.

Observe meantime what happens to trap A. The falling water increases the pressure in front of it, and reduces the pressure behind it. Air is therefore drawn into the pipe through trap A, and though this in itself would be harmless, the rush of air carries with it part of the water which should seal the trap. When the falling water has got below the point at which B joins the vertical pipe, the trap B is exposed to the same action, and a body of water falling through a soil pipe of even moderate height might unseal a number of traps. In the same way the discharge of water through trap B might draw the water from trap A as well as from B.

Prevention of Effect on Traps.—Such a glaring example as this could not occur in any system of drainage with even very elementary provision for ventilation. The continuation of the pipe right up past A to an opening above the roof would entirely prevent the reduction of pressure, and a *free* opening above the disconnecting trap would prevent the compression. (An "inlet" opening with a mica flap valve would not do so.) It is in fact clear that any disturbance of the water in traps, by the compression or exhaustion of air, can be made quite impossible; all that is needed is to provide openings whereby air can enter or leave with sufficient rapidity. The fluctuations of pressure are thus kept within limits so narrow that the water seal has sufficient power of resistance; and the only difficulty in doing this lies in the fact that these openings must be placed where escape of the contained gases will be harmless. Practically speaking, this means that they must end above the roof, except the one (called by courtesy the "air inlet") which is at the lower end. It has already been fully discussed (Chap. IX.).

The distinction is sometimes made between "ventilation" pipes, provided to give a through current of fresh air, and

"vent" pipes, provided to prevent the fluctuations of pressure. The distinction seems scarcely necessary, as a pipe provided for the one purpose will be of advantage for the other also, and the more general term "air pipes" is perhaps better than either.

General Requirements.—It is frequently said that every trap requires an air pipe, but this is too sweeping. For instance, a stack of soil pipes may have several branches going off almost horizontally and with a distance of not more than a foot or two between the vertical pipe and the traps (Fig. 73). To provide a special air pipe between the traps and the upright pipe would be needless, assuming that the passage of air through the main pipe was perfectly free both up and down. If, on the other hand, the branches were long, and especially if they were both long and more steeply inclined, the air pipe would be necessary. It is not easy to lay down a hard and fast rule as to when a special air pipe becomes necessary; it would usually be advisable (not so much to prevent syphoning as to permit free circulation of air) when the length of the branch got beyond 3 feet. Some bye-laws make 1 foot the limit, but if the conditions otherwise are good this is extreme. There are two points to be considered in connection with air pipes: Are they necessary (1) to prevent syphonage; or (2) to prevent stagnation of air in "dead-ends." If not, they should be left out. Special ventilating pipes have drawbacks as well as advantages, and unless a pipe actually serves some useful purpose, of sufficient importance to counterbalance the objection of extra complication, it should not be put in. Each foot of piping implies a chance of

Fig. 73.—Trap Ventilation Unnecessary.

something going wrong, and while the designer thinks he is erring on the safe side by increasing the complication, he is really in many cases merely increasing the chance of mischief.

Termination of Air Pipes.—These should follow the same rule as soil pipes, that is, they should have no open termination except above the roof. If the pipe to which the fitting is connected has no liquid entering it higher up, then there is no reason why the vent pipe should not simply be returned into the main pipe (Fig. 74). Or again, if there are connections at different levels, the air pipes from the various traps may be collected together, and this joint pipe returned into the main above the highest branch (Fig. 75). On no account must the air pipe return into the main *below* the highest water inlet, otherwise the air pipe will become polluted by this water flowing into it.

Fig. 74.—Air Pipe Returned to Soil Pipe.

In the case of waste fittings, it was at one time very common to run the air pipe through the wall, and terminate it just outside—probably beside a window. This slovenly method is fortunately becoming less common. If it is worth while to make waste pipes tight, and to trap the fittings, it is surely worth while to see that the air which may escape from these pipes is not provided with a direct means of entering the house by means of such air pipes and windows. If it is necessary to ventilate the traps, then the air pipes should either return into the main waste pipes as above, or should be carried independently above the roof.

Fig. 75.—Air Pipe Returned to Soil Pipe above highest connection.

Cross Connection.—With numerous air pipes there is a considerable danger of misconnection. One sometimes finds that the waste pipes are carefully "disconnected" from the drains and soil pipes, but that the air pipes from the two sets of fittings are connected. Whatever views may be held of the value of disconnection, it ought to be completely done if it is done at all.

Misconnection to Traps.—Air pipes are often connected to traps in a most unsatisfactory way. In Fig. 76 is shown an air pipe so connected that every discharge will wash sewage

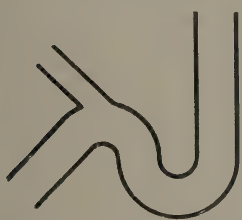

FIG. 76.—Air Pipe Badly Connected.

FIG. 77.—Air Pipe Properly Connected.

right up into it. This is easily avoided by care in making the connection. Fig. 77 shows where this should be done, far enough from the trap to be clear of the upward rush, and curved away from the flow.

Rust Pockets.—It has already been mentioned in connection with the ventilation of drains that pipes which are air pipes and nothing else are much more liable to obstruction than pipes which convey liquid matters. If the air pipe can be so arranged that any small particles of dirt which get into it will drop right down into the water-carrying pipe, these particles will be promptly washed away. But if an air pipe must have a fairly sharp bend near its lower end, in which such particles would lodge, it may be desirable to use a branch instead of a bend on the pipe, so as to form what is called a "rust pocket." The two methods are shown in Fig. 78. If the pocket is provided with a screw plug, anything which gathers may be

cleared out from time to time. On the other hand this rust pocket is apt to hold water (from condensation or otherwise), and so may suffer in the event of a severe frost. It is best if possible to have the pipe so free from bends that rust or other obstructive material will not accumulate.

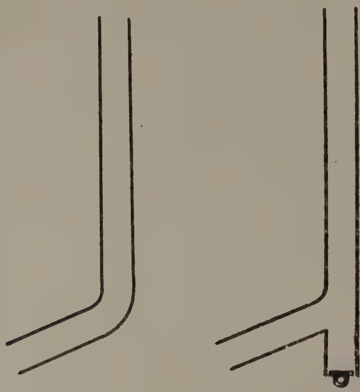

Fig. 78.—Plain Bend and "Rust Pocket."

Sagging of Air Pipes.—One main air pipe may be connected to a considerable number of traps, and it is essential to see that the branch air pipes are so arranged that they will remain free from obstruction. If a pipe were formed as shown in Fig. 79 with the middle lower than either of the ends, it would sooner or later become water-logged and useless. But it is of comparatively little consequence although the middle is higher than the ends, as shown by the dotted lines in the same figure. There is nothing in that arrangement to hinder the free flow of air, when this is wanted to protect the water in the trap from disturbance.

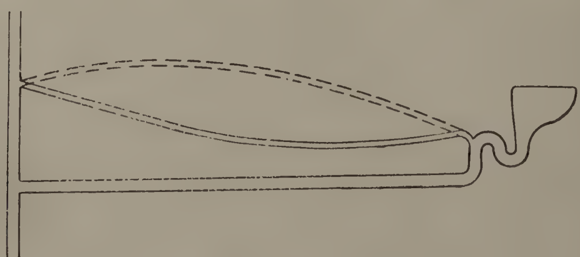

Fig. 79.—Sagged Air Pipe.

Size of Air Pipes.—The air must pass with sufficient freedom to prevent any appreciable alteration of pressure due to

the movement of water. Practically, it has been found that when the soil pipe is carried full size to its upper termination a main air pipe of 3 inches in diameter, with branches to the individual closet traps of $2\frac{1}{2}$ inches or even 2 inches, is sufficient to obviate any risk, even when the 3-inch pipe is branched into the main soil pipe extension as shown in Fig. 74. The case of a very lofty building would be an exception, as the velocity attained by the falling water would be very great, and the friction of the air in the long pipe would be considerable. When the waste pipes are separate from the soil pipes it may be taken as a general rule that a main waste pipe, connected with a number of baths, basins, etc., should have a main air pipe of $2\frac{1}{2}$ inches or 3 inches in diameter, and that if the bath traps are 3 inches the air pipes from them should be 2 inches. It is not as a rule desirable to have air pipes of less than an inch in diameter from even the smallest traps, but when the choice is between a smaller air pipe or none, a $\frac{3}{4}$-inch pipe may sometimes be used.

When the trap to be ventilated is about the ground level—that is, when there is little or no vertical pipe below the fitting—there is not the same risk of "syphonage," as the water never acquires a high velocity in the pipe. In such a case, unless when a larger air pipe is needed for purposes of drain ventilation, there may be no need for carrying the air pipe to the roof of the same size as if it were the continuation of a soil pipe. A 3-inch pipe would be quite sufficient ventilation for the trap of a closet, unless this were the termination of a drain. This, however, must be applied with some discretion; if there is any considerable length of vertical pipe the justification for the smaller air pipe does not hold. An illustration dating from the early days of sanitary work is still instructive. In a town house whose total height was about 60 feet there was a pan closet one stair up, that is, about 14 feet from the ground. This was removed, and a valve closet put in its place, a 3-inch air pipe being at the same time carried up to the roof. The soil pipe, $4\frac{1}{2}$ inches in diameter, ended at the closet. Every time that the closet was discharged, the trap was "syphoned," and it was proved, by cutting off the air pipe

a foot or two above the closet, that the cause was the excessive friction due to the long pipe. A short air pipe 3 inches in diameter was sufficient to prevent any movement in the trap, but when the air had to be drawn through about 50 feet of this pipe the result was totally different. An air pipe $3\frac{1}{2}$ inches in diameter was sufficient for the purpose.

Terminals.—Where an air pipe of other than small size is carried above the roof, the wire ball grating (Fig. 42, p. 103) is the most suitable finish. For small pipes a single wire across the top is sufficient. A pipe too small to be obstructed by birds does not need any protection.

Material.—As these pipes are very largely inside, and thus have to be bent into suitable shapes, lead is commonly used. It has the further advantage over iron that there is nothing to scale off and choke the pipes. It is desirable that the lead should be of the same thickness as is used for other sanitary work, that is, equal to 8 lbs. per square foot (see p. 100). As against the advantages, lead has the serious disadvantage that it can be readily damaged, and as a matter of fact is often pierced by nails.

CHAPTER XX

DESIGNING A SYSTEM OF DRAINAGE

When an engineer is called on to design a system of drainage for a house or other building, it may either be that the building is still to be erected, or that an old system of drainage is to be replaced by a new one. The same general principles must be followed, but their application differs in some important respects.

New Buildings.—When the building is only projected, it is possible to consider drainage requirements before the plans are finally completed. A comparatively small change in the position of some appliance may make a considerable difference in the plan of drainage; and while of course general considerations of planning must overrule any questions of detail, it is often possible to simplify the drainage without any disadvantage in other respects. If therefore the engineer is consulted before the plans are otherwise completed, he will endeavour as far as possible to secure the following:

1. That the sanitary equipment is grouped, and especially that no drain of considerable length is needed for one single fitting.
2. That the sewage drains are as few and short as possible, and that all the flow gets into the main channels without long branches.
3. That at the upper end of every drain it is practicable to carry an air pipe to a sufficient height without having it other than vertical.

Re-draining an Old Building.—In re-draining an old building the existing position of fittings has usually to be accepted, unless when the re-drainage is accompanied by a general remodelling of the place.

Preparing a Plan.—The first step in preparing a drainage plan is to make a plan showing the outfall (or outfalls), the position and nature of every fitting from which drainage will originate, and the position of the rain pipes. This forms a skeleton which is to be completed by showing the drains, with all their accessories of traps, manholes, and the like.

Levels.—Before the lines of drain can be fixed information as to level must be obtained. All the levels should be referred to some mark which will not be disturbed during the progress of the work; and on large work it is usually convenient to take levels with reference to the Ordnance Bench Marks. On small works this is often needless, but the levels should always be referred to some definite and permanent mark. The most convenient method of levelling is usually that of taking a number of "spot levels"—the level of the ground, or of the invert of pipes, being calculated out with reference to the datum point and marked on the plan at the proper places. Assuming that these points are sufficiently numerous and judiciously selected, it is easy to draw trial sections with sufficient accuracy, and in many cases a working section can be prepared from them. For instance, the working sections for the system of drainage shown in Fig. 84 were drawn from spot levels taken as indicated on that plan by crosses.

Invert Level.—As has been said, some of these levels will be on the ground surface and others on the "invert" of pipes. Care must be taken to avoid confusion, and it is desirable to take ground level also wherever an invert level is taken, and to use different colours in putting the figures on the plan. Red figures for example may be used to indicate surface levels, while invert levels are marked in blue. The "invert" is the inside bottom of the pipe, often called the "water-run," and this is the level from which all calculations of gradient are made. The invert level of the outfall is the key to the whole work, and the lowest level at which an outfall can be got should be marked on the plan. It should be noted, however, that when pipes of different diameter are used, the invert at the

junction should drop at least half the difference, sometimes the whole difference—that is, the inside top of the pipe, or at least the centre line of the pipe and not the bottom line, should continue straight. This is of consequence chiefly when gradients are very flat, and it is in such circumstances that it

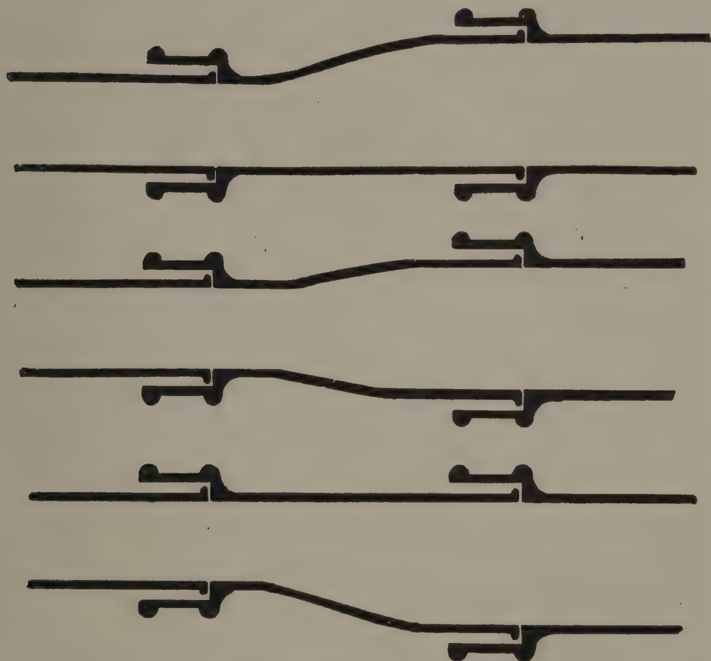

FIG. 80.—Enlargement of Drain Pipes.

is most apt to be overlooked. Suppose the enlargement shown in Fig. 80 to be required because a branch or branches come in, and to be made as in the top illustration. The smaller part will be completely waterlogged before the carrying capacity of the enlarged pipe is nearly reached. In the middle illustration this objection is partly, and in the lower one wholly, removed.

Fall for Traps.—It is desirable that each trap should have a fall of 1 or 2 inches, and some types (such as that shown in

Fig. 22 (p. 73) require considerably more. Allowance must therefore be made for any traps through which the sewage has to pass.

Depth of Pipe from Surface.—When pipes pass underground the invert must be sufficiently below the surface to allow for (1) the size of the pipe itself, and (2) a sufficient covering. The first includes:—the inside diameter, the thickness of the material, and the projection of the faucets; the second depends on the kind of pipe, the nature of the traffic which it has to stand, and the character of the covering. As the system of drainage under consideration is that of a private house or establishment the traffic is less varied and heavy than street traffic, but if it is under a road of any sort the pipe should be strong enough to stand ordinary cart traffic. With an ordinary macadam surface, a stoneware pipe would usually be safe with 2 feet of cover over the highest part of the pipe. An iron pipe might do with half that cover; while if the surface is strong and unyielding the top of the pipe might almost be in contact with the covering. Where only foot traffic is possible the conditions are easier, while in garden ground the cover is needed chiefly to protect the pipe against accidental injury from garden tools. The necessary difference between surface and invert level might thus be only 8 or 9 inches in one set of circumstances, and 3 feet in another.

Pipes above Ground.—It is not always necessary that a pipe should immediately pass under ground. When gradient is limited, it is sometimes possible to economise it by carrying a pipe above ground for some distance. A sink branch for example comes through the wall about a couple of feet above ground; instead of allowing it to go down vertically, the pipe may be carried along the outside face of the wall at a suitable gradient, so that when a place is reached where cover is essential the sewage has been conveyed some distance nearer the outfall (Fig. 81). This can seldom be done to any great extent—on account of doorways and other obstacles—but even a slight saving of fall may be of considerable value.

Raising the Ground Level.—This may be done to gain fall at the upper end, or to save loss further down. In laying out a system of drainage it is important to see that the gradients will not bring the pipe too near the surface in crossing any depression; or if they do, that the depression may be conveniently filled up to the extent required. This is a difficulty which frequently occurs in sewerage works, and though it is less likely to occur in works on a smaller scale and in private ground, its possibility must not be overlooked. When the preliminary levelling operations indicate that there is likely to be a deficiency in fall, the upper ends should be carefully

FIG. 81.—A Method of Saving Fall.

gone over to see whether by making up the ground, or by keeping the pipes above ground as suggested in the preceding paragraph, anything can be gained. The filling up of intermediate depressions belongs to a later part of the design.

The "Water-parting."—Each building, or each block of a large building, will naturally have a drain on either side of it. At the end most distant from the outfall there may be a part of the system which might be connected either to the drain on one side or on the other. The configuration of the ground may leave little room for doubt, for if there is a well-marked ridge on the ground it is naturally accepted as the water-parting. But when there is doubt as to where the water-parting should be, the following considerations should be kept in mind.

1. The sewage should travel by the shortest route. Other

things being equal, the connection will be taken by the route which gives the shortest distance to the outlet.

2. No drain should be needlessly fouled. This may compete with the foregoing. If, for example, a building has a drain on either side, but the drain on one side carries nothing but rain-water, while the other carries sewage, a soil or waste connection at the most distant point would naturally be led into the drain which was already polluted, even if the distance was somewhat greater.

3. The connection should be made where it will be of most value. For example, it is always desirable to have a drain ventilated by a soil pipe rather than by a special air pipe; if one side is already well provided with such means of ventilation, while the other is not, and if at the extreme end a soil pipe might be connected to either one or other (both being already fouled) the one which is not otherwise well ventilated should be connected with the soil pipe. The most probable case would be where a scullery sink came in near the head of the drain; here the soil pipe connection would be of value both for ventilating and scouring. Fig. 83 (p. 180) shows a drainage system which illustrates this. The system is in three sections, the centre one being required to drain a sunk flat containing a bathroom. The drain from A and B would naturally have joined that deep drain at C, but as the deep drain was well provided with flushing and ventilation, the connection was carried instead to D, where there is a scullery sink, so that the soil pipes A and B serve to ventilate the scullery section, and the flow from these pipes helps to scour it.

4. The flatter the drain the more need there is to see that it has plenty to do.

These various considerations are of varying weight, and the skill of the designer is shown in producing the plan best suited to the special conditions of each case.

Drains through Buildings.—In the case of continuous buildings, with a sewer either at the front or at the back, but not both, a drain through the building is inevitable. Even in detached buildings it occasionally happens that a drain through

some part can only be avoided by a circuitous route, or by putting the drain in some very inaccessible position. The circuitous route implies probably worse gradients, and certainly a greater length of fouled channel, and these may readily be more objectionable than the mere fact that a drain passes inside the building. It is therefore unwise to lay down a hard-and-fast rule; other things being equal, drains should be kept outside, but if some important advantage is to be gained, or some serious disadvantage to be avoided, there need be no hesitation in passing inside. The low level drain in Fig. 83 is taken through the building as above described, to save a deep cutting round the end. This cutting would have been far below the foundation, and might have affected the structural stability of the building. When a drain is inside it should, if possible, pass through in one unbroken straight line, with an access opening outside at either end rather than inside the building. If an important drain must be taken through a building it may be worth while to construct a culvert by which the drain will be at any time accessible, and which may often be utilised for other purposes. This was done in the case just mentioned. In Fig. 84 again (the drain plan of a poorhouse) it will be seen that at three places the drain is carried through the building, and an examination of the plan will show how greatly the length of route (say from A to the outfall) would have been increased if this had been barred. Cellar space may sometimes be used, the drain being carried clear above the floor on independent supports. It need scarcely be said that for inside work cast iron pipes only should be used and that no stoneware or fireclay pipes should be employed in such a position.

A common provision in building regulations is that when stoneware or fireclay pipes are laid under a building they must be cased in concrete to a thickness of at least 6 inches all round. This regulation may be of some service indirectly, as it tends to make the use of such pipes very costly and, therefore, improbable. From any other point of view the regulation is a model of absurdity, as it renders the drain inaccessible without by any means making it gas-tight. If a

pipe is not fit to pass through a building without such reinforcement it is not fit to pass at all, and however unsatisfactory stoneware or fireclay may be for such a purpose, they are much more likely to be water and air-tight than is ordinary concrete. It is rather a severe reflection on modern engineering practice to suggest that a wall over 6 inches thick is needed to retain a working pressure of an ounce or less to the square inch, or an emergency pressure which, even with a choked drain, would not exceed a few pounds.

The Draft Plan.—Having noted all the levels and indicated where alteration is possible by keeping pipes above ground, by banking or otherwise, the lines of drain can then be drafted. The general principles already discussed are kept in view, and the draft is carefully examined to make sure (1) that it does not clash with any physical feature of the ground; and (2) that every required connection has been provided. Such revision may prevent the adoption of a line which runs over a place where sufficient cover is not available, or which interferes with trees, or which crosses some other pipe line (steam, water, gas) at an unsuitable height. Such objections, and the possibility of overlooked connections, may be regarded as the radical and fairly obvious faults from which the plan must be freed; but even when that has been done the plan may bristle with less obvious, but still very serious, defects. The rule-of-thumb designer stops at this point.

Simplicity.—A further revision is made to see if no simplification can be effected. Assuming that the customary method of separating the waste water from the main drain by traps is adopted, it may be possible to make one trap serve for more than one branch. For example, there may be a pantry sink and a lavatory basin in close proximity, and it might be advantageous to make an arrangement such as that shown at E in Fig. 83. If on the other hand they were further apart, the advantage of saving a trap might be more than balanced by the increased length of pipe. Fig. 82 illustrates a very popular but a very undesirable way of saving traps. It repre-

sents an actual case in which the soil drain was almost filled with deposit. The flow of water which ought to be concentrated in one pipe is divided between two, with the

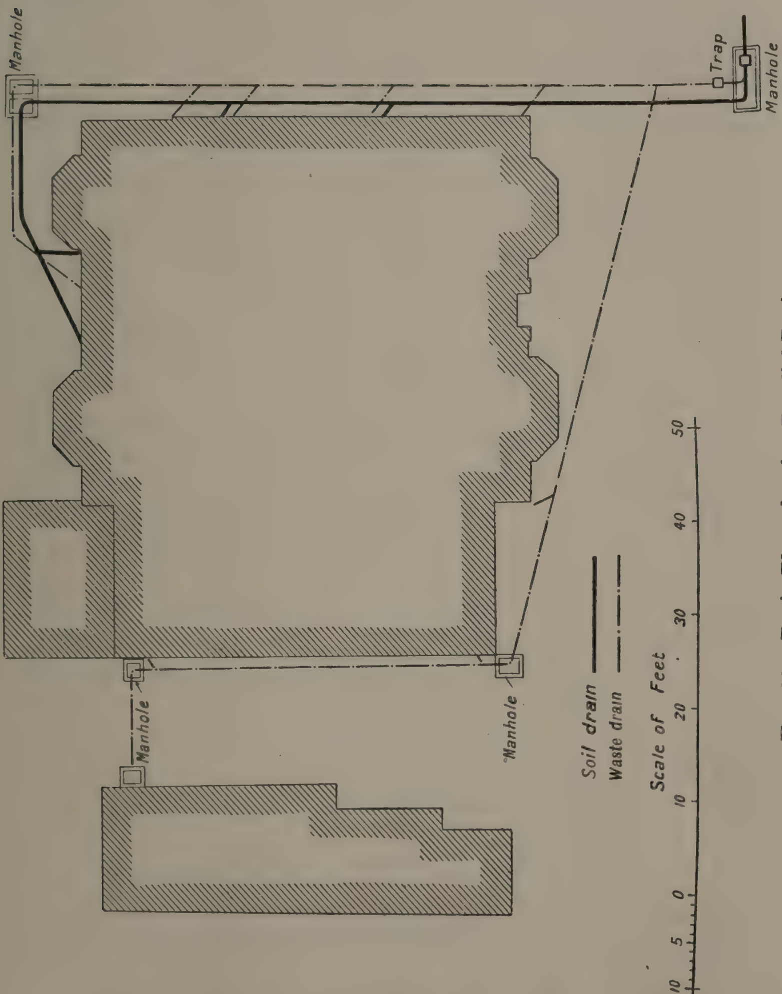

FIG. 82.—Drain Plan, showing Parallel Drains.

result that neither one nor other is so well flushed as a single pipe would be. It is impossible to give any rule as to where this method becomes undesirable, but if the problem

were treated merely as a financial one, and the method preferred which would cost least, the result would as a rule be fairly satisfactory from a sanitary point of view. When two pipes run parallel for any distance the design is probably bad.

General Considerations.—The limiting gradients, with or without flushing, should be considered in the light of the principles laid down in Chaps. VI. and VII. It must be remembered that in the case of a drain which has little to do the gradient must be greater than in one where the flow is ample, and it may be desirable to give more fall at the upper and less used part of a drain, even at the cost of a greater flatness near the outfall.

The gradient of branches, except those at the extreme upper end, is not usually a matter of any difficulty. The main drain gets deeper and deeper as it comes nearer the outfall, and there is thus a good fall into it from any of the branches except those near the top.

While in many cases the nature of the ground and the position of the required connections mark out the main line of drainage with considerable precision, it often happens that there is little to choose between two or more routes. In that case a draft plan should be drawn for each, and an estimate of cost made out. As a rule, the least costly is the best if the saving is in pipes and traps, although if an alternative route is somewhat more costly on account of more difficult ground, but has less piping, it may possibly be better. But unless one general plan is very evidently the best the engineer will look into every circumstance, present or prospective, which may determine his choice. The way in which the ground about the building is to be used—lawns, flower-plots, drives, walks, and the like—will be considered in the case of a country house or institution; while in a town building the different kinds of streets, courts, passages, etc., will be taken into account. It will be remembered that while the pipes are to be completely buried, the gratings have to be constantly open, and the manholes must be accessible whenever required; the pipes,

therefore, may be carried through ground where a grating or even a manhole would be out of place.

It is desirable that when at all possible the upper end of the main drain, and of each section, should be a soil pipe and not a special air pipe. When one or more waste or rain pipes join the main further up than the highest soil pipe it is desirable to put the trap which disconnects these at the point where the main drain is joined and not close to the individual waste pipe. By this means the soil pipe ventilates the head of the main drain, and there is no need for a special air pipe. In Fig. 102, for example, if instead of the traps at F and G one trap were placed at E, it would have been unnecessary to provide an air pipe at G.

The desirability of having as much of the drain as possible free from anything but rain-water has also been mentioned. When a drain carries nothing but rain-water the extreme care required for sewage drains may not be necessary, and it may often be permissible to use fireclay or stoneware pipes. It is undesirable to multiply traps which are dependent on rain-water for their efficiency. In a long spell of dry weather such traps may become dry, and if they have to be filled by hand there is an obvious advantage in reducing their number.

It is desirable, therefore, to gather the rain pipes into groups, and to run them into the main drain either at the manholes as shown in Fig. 37, or through a separate trap as shown in Fig. 32. The former of these has the advantage that evaporation is lessened. There is no advantage in discharging the rain-water into the main drain as low down as possible: on the contrary, rain-water is a valuable flushing agent, and should enter the main as far up as possible. If a large quantity of rain-water is to be introduced at one point it may necessitate an increase of diameter at that point, and of course this can be most conveniently arranged at a manhole.

Examples.—Four examples of drain plans are given in order to illustrate the various problems. Reference has already been made to various features in these plans, and it should be explained that they are taken from actual practice, and that

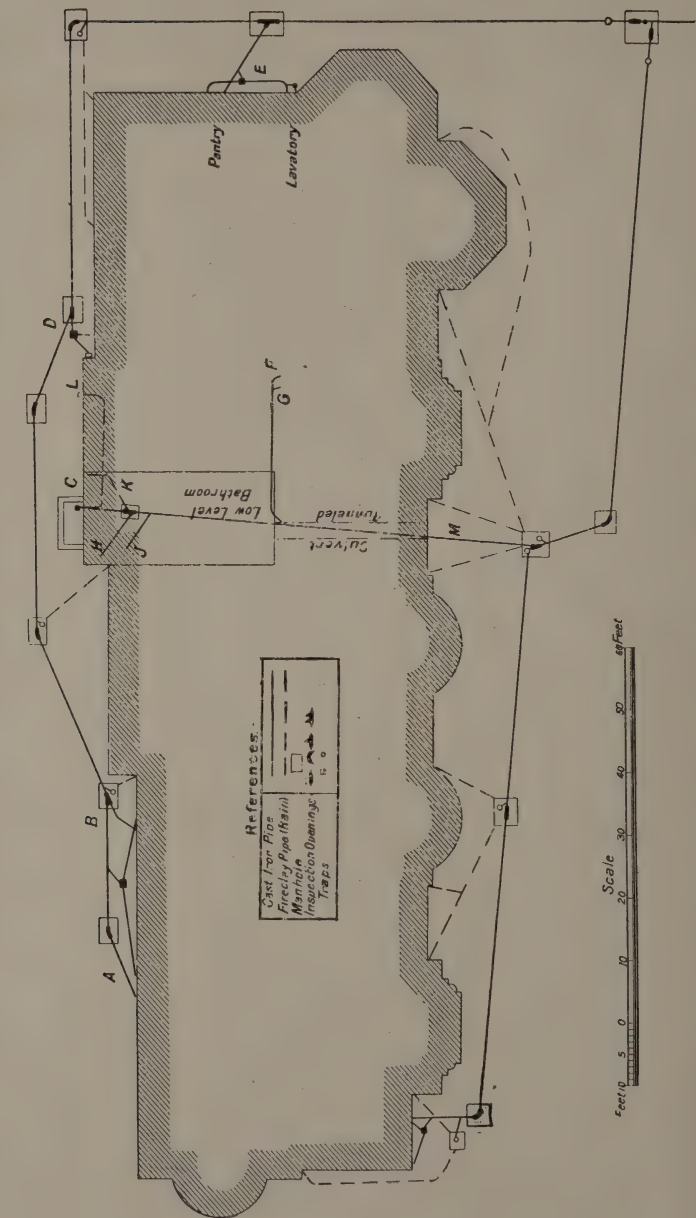

FIG. 83.—Drain Plan, showing Re-constructed Drainage.

the arrangements therefore are not what would always in theory be the best, but what had actually to be done to meet the circumstances of the case.

Fig. 83 represents a mansion house which had grown by successive additions. The chief feature in its drain plan—the deep drain through the house—has already been mentioned. The basement extended over only a small part of the centre, and the other parts were not founded very deeply. The sanitary accommodation was scattered all over the building, and a considerable extent of drain was thus needed. Except for the basement, there was ample fall. The branches which join the main drain untrapped are all from soil pipes, except at two places. F and G are respectively a soil pipe and a waste pipe, originating in a bathroom on an upper floor. (The wing to the right is of less height, and so the bathroom has a gable window, although on the ground plan it is in the centre of the house.) Further, in the basement, while H is a closet, J and K are bath and basin. If disconnection had been carried out there, it would have been necessary to lead a duplicate pipe right through the house, with a trap in the neighbourhood of M. Each bath and basin which would thus have been "disconnected" is in the same apartment as a closet, and it was considered that the extra length of dirty pipe and the extra trap would be much more objectionable from a sanitary point of view than non-disconnection of these fittings. The matter is discussed generally in Chap. IX. At C there is a sunk window with a surface trap, over which discharge a rain pipe and a pipe from a heating chamber at L. The whole system was proved tight by air pressure.

Fig. 84 represents the drainage system of a poorhouse, which also had grown from a small beginning by the addition of wing after wing. The drains were of varying age and quality, and with some repair were made to serve as a rain-water system. The discharge was into a tidal river, and tank treatment, but not filtration, was required.

It was decided to construct a new set of iron drains receiving nothing but sewage, the rain-water being taken by the old system. A ground plan was available, and the preliminary

survey took the form of "spot" levelling as before mentioned, the position of each of these levels being indicated on the plan by a cross. The fall was very limited, and a flushing tank was placed at the head of several of the branches. Thereafter the drains were laid out on the principles described. The soil being open and sandy and unskilled labour being always abundant, it was possible in many places to dispense with built manholes; and although access openings, as in Fig. 35, were liberally provided, many of these are only available after digging. Many of them are so shallow that they can be reached in a few minutes, while the others are so situated that no great harm will result from the disturbance. It was decided therefore that the certain saving attained by dispensing with built manholes was worth the risk of disturbance later. It will be observed that by removing the proper access covers it is possible to see through practically any part of the drain, or to pass rods through if that should be required.

Fig. 85 is the drain plan of a small infectious diseases hospital. The buildings are modern, but the drains were found to be unsatisfactory. They were renewed in iron, and as in such a building it is desirable to reduce possible work to a minimum, built manholes were freely provided. The rain-water is taken into the same system, but the roof and paved area is small, so the rain water is not a serious matter. The building on the left contains office and accommodation for matron and nurses; the small building is the gatehouse, while the building to the right contains mortuary, washhouse, stabling for ambulance, etc. The drains connect with a public system of sewers. In the main building a flushing tank is provided, which flushes the drains on each side by the nearest manhole. The arrangement of receiving the rain-water through traps in the manholes and by separate traps (referred to on p. 179) is clearly shown on this plan.

Fig. 86 represents the drain plan of a country residence of moderate size, in which the drains were designed as part of the original plan. The main trap is at A, and from that the drain is carried through a manhole at B to another manhole at C, the garden plan preventing a direct line from A to C.

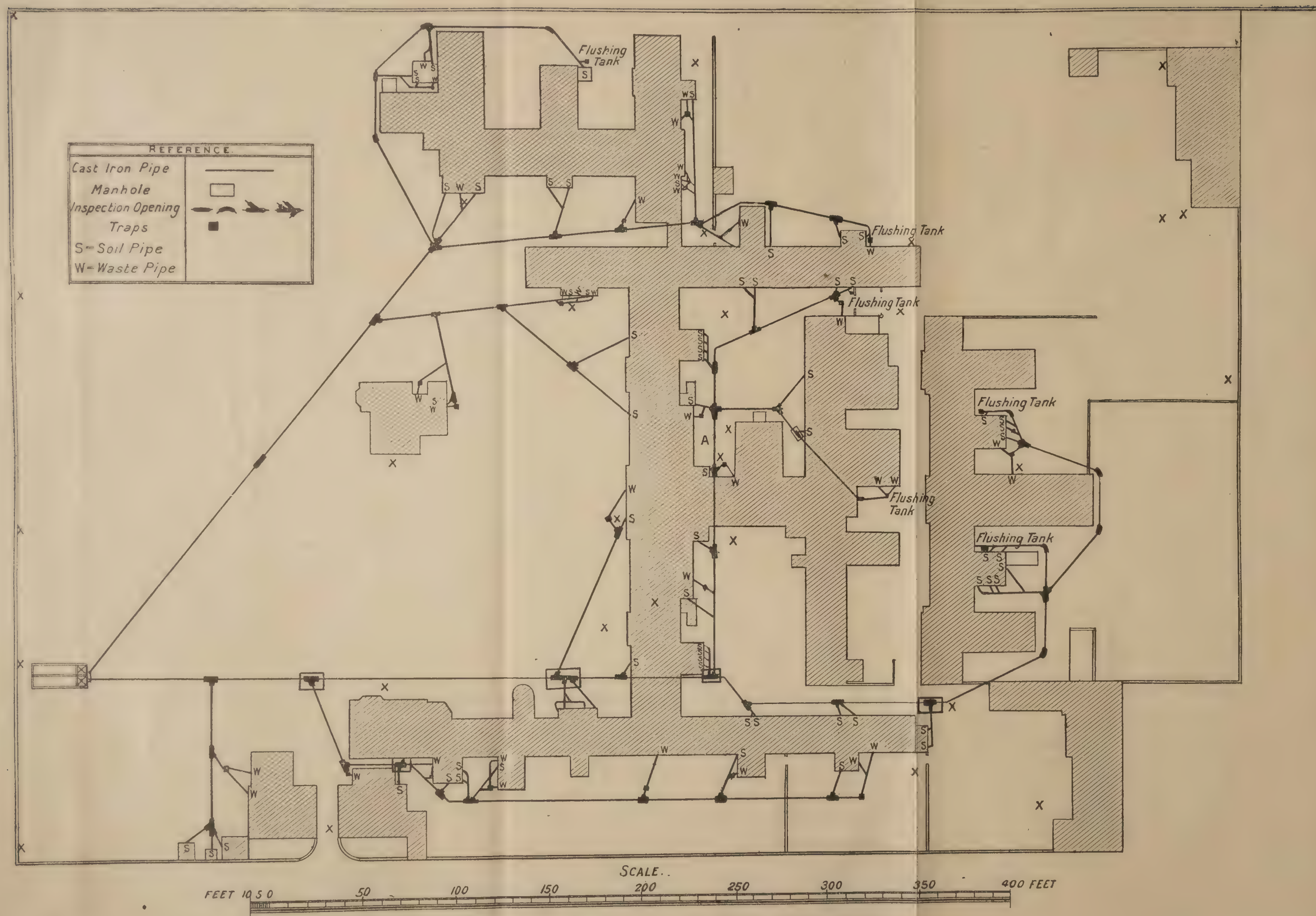

FIG. 84.—Drain Plan, Poorhouse. No Rain-water Taken.

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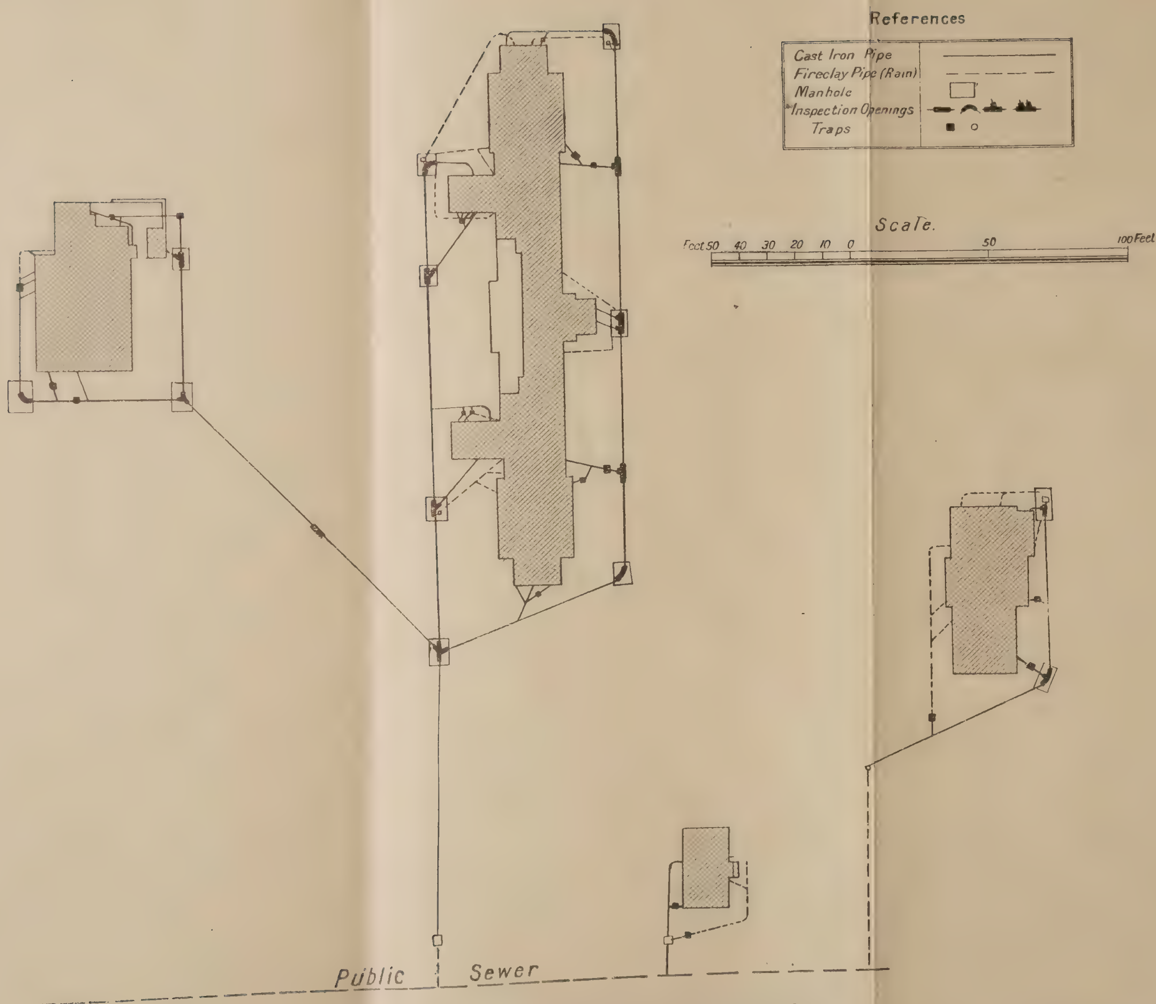

FIG. 85.—Drain Plan, Infectious Diseases Hospital.

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At C the drain divides into several branches. One branch is trapped by a trap in the manhole itself, and is carried round the house through various manholes to D. Each of the branches into this drain is from a bedroom basin on the upper floor, each with a waste pipe carried full size above the roof, thereby providing for free ventilation at the upper end. The manhole C and the trap are under the drive, and an open grating at that point is inadmissible, hence the grating is carried to the point E (in the shrubbery) and may serve either as "air-inlet" or outlet—providing in either case, in conjunction with the openings above the roof, a free circulation of air. The branches which enter this section through traps are rain pipes only; and apart from any other reason for trapping them, it is possible to apply a pressure test to the waste water section without stopping any of the rain pipes.

The central branch runs to F, where it connects with a soil pipe (untrapped) and a waste pipe (through a trap), these being from a closet and a bathroom on the upper floor. A branch of the main drain turns off to G and H. At G a cloakroom closet (with an air pipe to the roof) joins the main drain, while a trap in the manhole floor receives rain-water and also the waste water from a flower pantry, which it is assumed will be of the same character as rain-water. At H the direct line comes from a soil pipe with two closets, one on each floor, while the branch is from a soil pipe connecting with a closet and a slop sink, both on the upper floor. The waste branch is from a cloakroom basin and a servant's bath, both entering through one trap. The trap in the manhole floor takes the discharge from a "hydro-vacuum" cleaning apparatus, in addition to the rain-water.

The direct line of the main drain goes from C on to J. The manhole there is provided not only to give access to the drain, but to take through its floor trap the waste water from the heating plant, as well as rain-water and some subsoil drains. At this point also the drain, which has been kept deep to drain the heating chamber, is brought to a higher level by the vertical bend as shown on the small section drawn

just above it. At K there is a branch to the kitchen department, passing on through L and M. The trapped branch between K and L is for the washhouse, and at the upper end there are connections for (1) the scullery sink, and (2) a bathroom on the upper floor. The scullery sink discharges into a flushing grease box of the type shown in Fig. 31, fed by a flushing tank in the scullery. The upper end of the drain had to terminate in a special air pipe, which would not have been done had it been possible to arrange that a closet should join the drain about this place.

The outbuilding accommodates a petrol gas plant and a pumping set, the latter consisting of petrol engine, dynamo, accummulators, motor and pump. The branch at N is from a lavatory closet, and a full-sized air pipe to the roof at this point ventilates the upper end of the whole system. The dotted line at the trap just beyond is the waste from a water motor which drives the gas plant.

The drain, other than the short waste branches, is 4 inches diameter throughout, and the soil pipes and air pipes are the same. The waste connections and their air pipes are 3 inches in diameter.

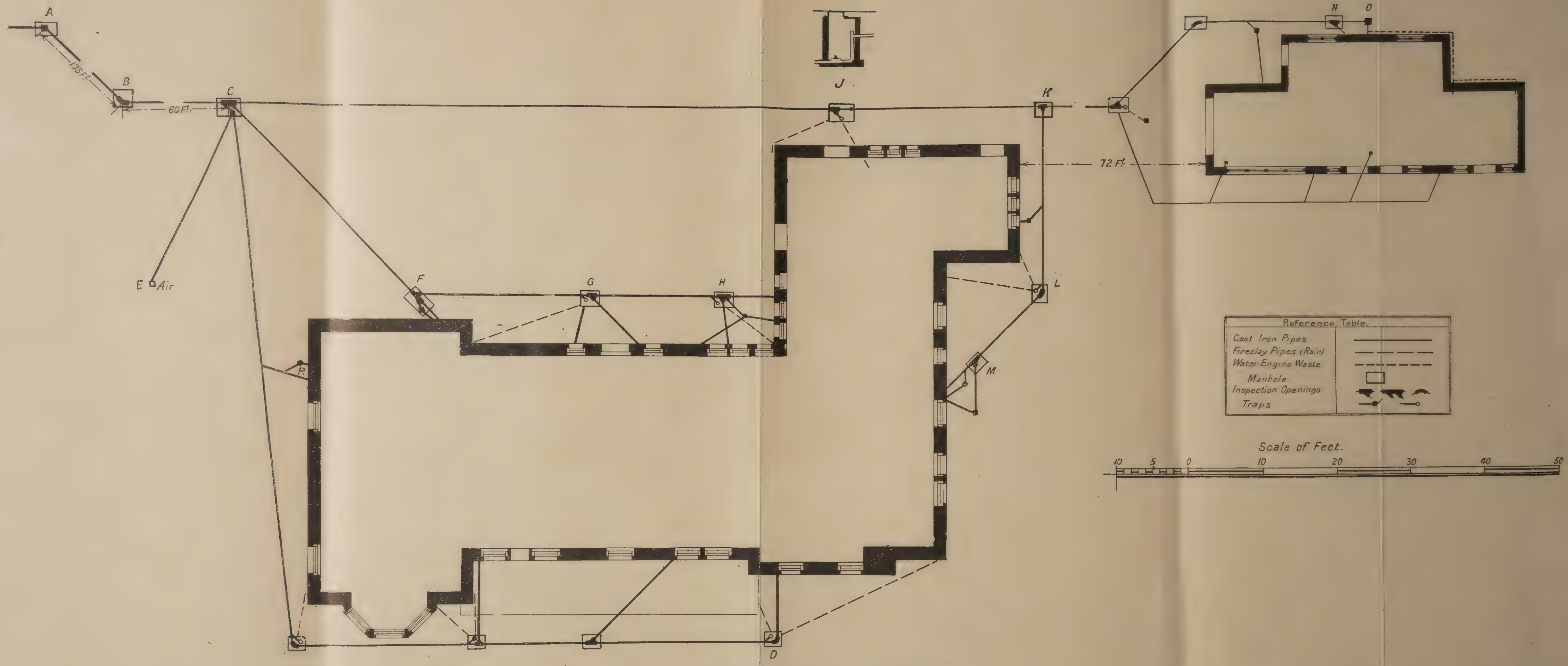

FIG. 86.—Drain Plan, New Country House.

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CHAPTER XXI

BUILDINGS OF SPECIAL CLASS—HOSPITALS, SCHOOLS, ETC.

While the principles of drainage do not vary, their application is often modified by special circumstances. Some of these have been considered under their respective headings in the foregoing chapters, and there are others which may conveniently be noted now.

Chief among the special circumstances are the uses to which buildings are put, and the following call for special consideration :

Hospitals.

Drain Plan : Disconnection.—The fittings are grouped more than in an ordinary dwelling, and the drain plan is modified accordingly. The case for "disconnection" (as between waste and soil pipes) is as a rule somewhat strengthened. While the closets and slop sinks connect direct into the main drainage system, with no intervening trap, the baths and basins may very properly discharge under (not over) the grating of an outside trap. In theory there is no reason why this should be necessary in hospitals more than in private houses, but in addition to the sentimental reason that no precaution is too great for such a place, it is to be remembered that as the fittings are grouped fewer traps are needed in proportion, that as the use of water is more lavish there is shorter retention of dirty water in the traps, and that there is frequently more room. There is not the absurdity of separating by traps pipes originating in the same apartment, and in a large establishment it is convenient for testing purposes to have comparatively small sections of waste piping with a trap from which each section can be tested.

Fittings.—The special fittings required for hospital work constitute the chief difference from ordinary buildings. The difference occurs in closets, baths, and lavatories, for different reasons—the helpless condition of the patients and the need for scrupulous cleanliness.

Closets do not differ from those in ordinary dwellings, except that they may be fitted with special contrivances to aid the patients who are partially incapacitated in supporting themselves and changing their position. But as a large proportion of the patients are unable to leave their beds, and as therefore bed pans and urine bottles have to be used, it is essential that provision should be made for emptying and cleansing those. For this purpose slop sinks are provided, and these are fitted with water jets in various forms. The sink is so arranged that the excretal matter can be flushed through it into the soil pipe, just as in an ordinary closet, while the jets are arranged for the convenient cleansing of the portable utensils. A typical arrangement is shown in Fig. 87.

In the case of baths, the primary requirements are well met by baths such as white enamelled fireclay or porcelain, standing on an impervious floor. But for the use of patients who have to be put into and removed from the bath by attendants, it is necessary to have free space on each side of the bath as well as a considerable space at the end of the bath. It is much easier to bring the patient "end on," and therefore sufficient length in the line of the bath is needed. This makes a somewhat serious demand on space, and in order to economise space swivelled baths have been introduced (Fig. 88). This bath has a fixed trap, but the connection above the trap leaves the bath free to revolve. It can therefore be turned to whatever position is for the time most suitable, and besides the economy of space, this has the obvious advantage that it leaves all the floor accessible for cleaning.

Lavatory basins for ordinary use are not different from those already described, but for surgical use various refinements are added. The object is to give the user complete control over the supply and discharge of water without any occasion for using his hands. The supply of water, and the regulation

of its temperature, is therefore frequently controlled by the elbow, while the discharge is controlled by the foot or knee.

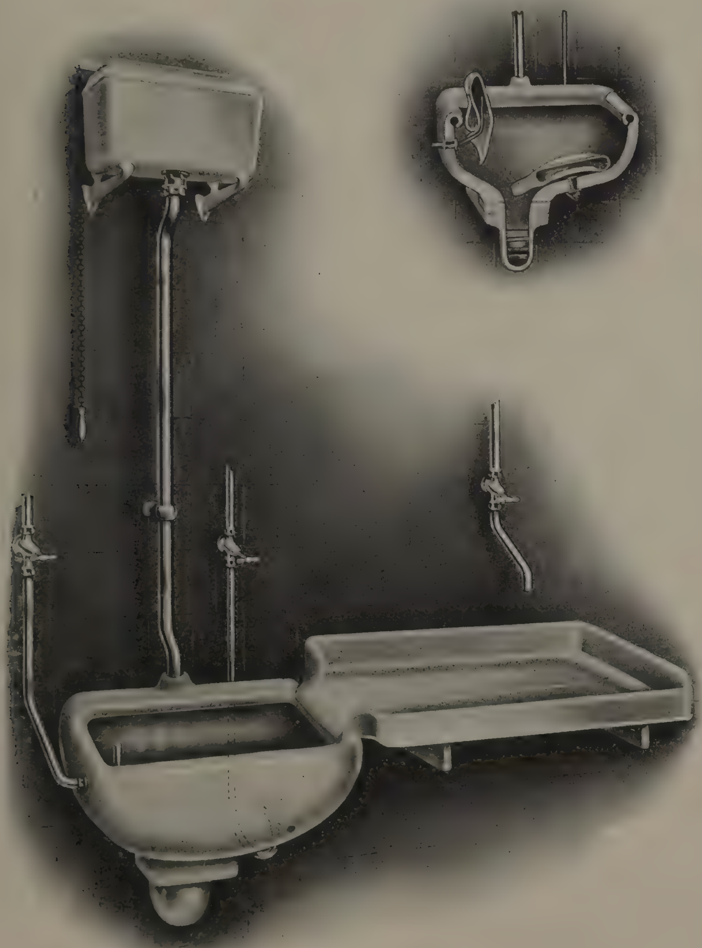

Fig. 87.—Hospital Slop Sink. (By permission of Messrs. Doulton & Co.)

A surgeon can thus command all the movements of the water while his hands are otherwise occupied, and he is free from

any risk associated with touching taps which might not be sterile.

Each bath and basin should have a trap close to its outgo, and the waste water should pass at once into closed pipes. The fashion which used to be popular of discharging into an open channel on the floor, is not satisfactory, as the alternate wetting and drying of the channel distributes particles of foul matter into the air.

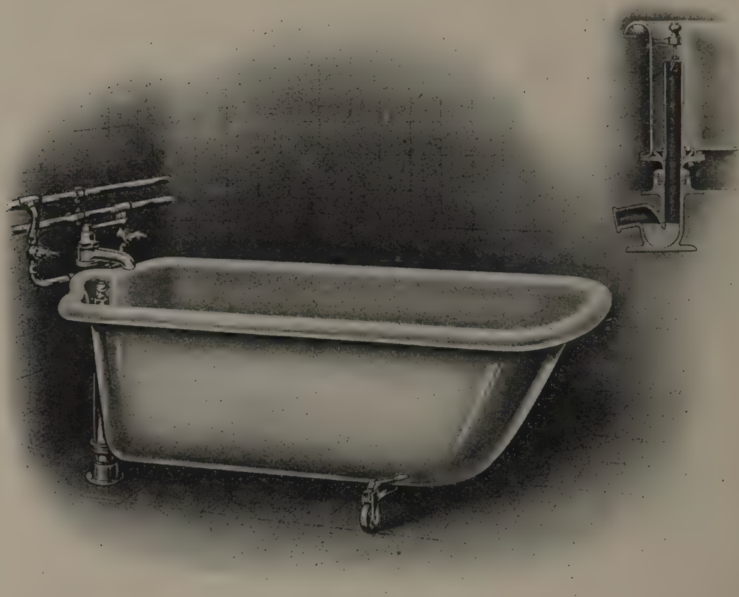

Fig. 88.—Revolving Bath. (By permission of Messrs. Doulton & Co.)

Schools.

In large modern schools drainage has to be provided for (1) the centralised blocks of closets, urinals, and lavatories for the use of the scholars; (2) closet and lavatory accommodation for the use of teachers; (3) sinks connected with special departments — cooking, laundry, laboratory, etc.; (4) wastes from drinking fountains; and (5) rain-water drains.

The closet accommodation is proportioned to the number of scholars for whom the school provides places, according to rules laid down by the Education Department. It is unnecessary to quote these rules here, as they are published in blue-book form at a trifling cost, and are of course in the hands of every-one who is concerned with work of this description.

Closets for Scholars.—School closets are becoming more and more like the best and simplest class of private house closets. It was at one time assumed that children could not be expected to attend to the flushing of closets after using them, and "trough closets" or latrines were the standard type. It is now, however, agreed that the school fittings ought to be such that they will inculcate as cleanly habits as are necessary at home; and when the water carriage system is becoming almost universal, it follows that the use of water-closets and the need for pulling the flushing handle will become equally so. Trough closets are rapidly being abandoned, and in many cases they would not be tolerated by the sanitary authorities even in rural districts. The single closet, arranged in groups discharging into one pipe, but trapped by itself and flushed by the user, is the only type which has any claim to consideration.

The use of all public or semi-public conveniences is apt to be rough, and strength and simplicity are of great importance. For this reason, as well as for considerations of cleanliness, wood is very little used. The closet buildings are usually built of enamelled brick, white or brown as taste or economy may dictate, and the partitions are of similar material. The floors are of concrete, and partitions and floors are so arranged that they may be washed with a hose. The most recent closets have no wood seats, but have a set-in rim (Fig. 89); and while the ordinary chain pull may be used to start the flushing discharge, it is often found better to use an arrangement less liable to damage. A satisfactory method is to have a bar sliding in a tube, with a projection only sufficient to give a fair hold, but not sufficient to apply much strain. This is shown in the figure. Closets are required to be of varying heights, to suit children of various ages, and this is most

conveniently managed by sinking those required to be low into the cement floor. The outgo, which is to be connected to the drain, must be sufficiently high to be clear of the floor, so as to allow a good joint to be made, even when the closet is set to the lowest possible position.

FIG. 89.—School Closet. (By permission of Messrs. Shanks & Co.)

Urinals.— These should be of smaller size, but otherwise should be of the same type as is provided in public conveniences. The recessing of the different stalls may be trifling, and there is no need for much projection of the partitions. An oiled slate back, without any recessing or partitions, is sometimes used, and, while scarcely so satisfactory, is more economical. The walls should be of glazed surface, not only to prevent the absorption of liquid, but to prevent the practice of scribbling on them.

Wash Basins.—It is highly desirable that washing should be done in running water, and the most satisfactory school basins are those which form a shallow trough, across which the water

flows. Each section of the trough is separate from its neighbour, and the amount of water which it holds is small. Unless, therefore, two children purposely use the same basin (for which there is scarcely room) no child can wash in water which has already been used by another. The flow of water is sufficient to replace the contents of the basin used during the time that one child leaves and another comes forward, and there is thus no chance of infection being spread. Numerous types of such basins have been devised. Fig. 90 shows a satisfactory method, and the same result may be

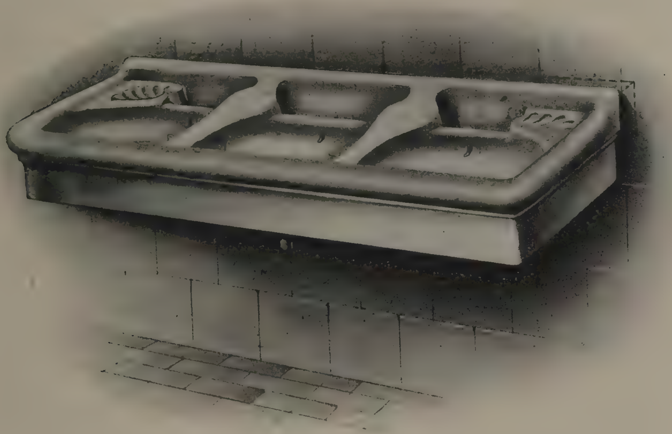

FIG. 90.—School Basins. (By permission of Messrs. Shanks & Co.)

obtained by using basins of the type shown in Fig. 91, though this is more commonly used for workshops and factories.

The chief use of the lavatories is at certain fixed times, and then by a large number. A considerable amount of washing has to be done in a few minutes, and the water is kept running all the time. The supply is not controlled by taps at the individual basins, but by one tap supplying the whole range, under the charge of the janitor or other attendant. If both hot and cold water are provided, he is responsible for

seeing that the supply is turned on at a proper temperature. To provide for casual requirements one or more basins may be fitted with individual control taps.

Baths.—Baths are being fitted in schools with increasing frequency. They are not greatly needed in day schools in which the scholars are drawn from a class with well-equipped homes, but for poorer schools they are of value. It is, of course, important to avoid all needless expense, both in the way of structural equipment and of water; and it is evident that the use of water in the form of spray or shower has great advantages over the use of water in bulk, as in plunge baths. If the water can be supplied under a reasonable pressure the spray bath is best, as it directs the water all over the body. A set of small compartments, with provision for hanging up clothes in a place protected from the spray, can be provided in a very limited space, and if the flow of water is turned on by an attendant for two periods—the first to allow the children to get thoroughly wet before soaping, and the second to wash off the soap—the consumption of water is small. The advantage of using throughout water which is absolutely clean—the used water passing away at once through a trapped grating in the floor—is of the utmost sanitary importance. The general question of spray baths is fully discussed in Chap. XVI., and the illustration on p. 146 shows how a set of such baths may be arranged (the illustration showing an installation not for a school, but for a foundry) in a very small space. The three baths there shown do not occupy more space than would be required for one plunge bath; and in a school, where not only are the users smaller than adults, but where strict privacy is not so essential, the allowance of space there shown would be very ample.

The construction of swimming baths is a matter which scarcely comes within the scope of this work.

Teachers' Accommodation.—Little need be said as to this. The class of equipment is exactly that of private houses; or in the case of schools with a large staff of teachers, that of

clubs or hotels. The arrangement of the space is a matter for the architect, and there are no engineering questions other than those which present themselves in connection with ordinary houses. The basins may be in ranges if the school is large; but these basins will be individual in every respect. In smaller schools the accommodation is usually in the form of one or more lavatories, each containing a closet and basin.

Sinks, Tubs, etc.—It is only in the case of laboratory sinks that any exceptional treatment is needed. In these it is important that the discharge should not come into contact with any material that may be damaged by the contents, and where acid discharges are probable it is best to keep the set of drains quite separate from the ordinary system, and to carry them independently to the outlet. Rain-water may be carried in the same drains, and stoneware or fireclay should be used not only for the drains, but if possible for the vertical pipes as well. The primary requirement of tightness is in such a case subordinated to the need of durability, and the exclusion of sewage matters makes tightness less important (compare p. 32).

All the other sinks and tubs should be treated as in an ordinary house, and should deliver into the ordinary drainage system, trapped in the same way as has already been considered in connection with house work (Chap. XVIII.).

Wastes from Drinking Fountains.—If there is a separate system of rain-water drains, it is often convenient that such wastes should join it. This arrangement ensures that in dry weather the main rain-water trap will have a fairly regular supply of water. Otherwise there is no reason why they should not connect with the ordinary main drainage system. The old drinking fountain and cups is now being to some extent superseded by the jet fountain, which throws up a small jet of water to be received direct into the mouth, thereby saving water and reducing the risk of infection.

Rain-water Drains.—The question may naturally arise whether or not the drainage should be on the separate system.

If the whole area is so small that a 5-inch main drain is sufficient for every purpose, and if there are no chemical wastes calling for special treatment, there is no reason, so far as the school is concerned, why the separate system should be adopted. Even if a 6-inch drain is needed the balance of cost will be in favour of the combined system, and there is little to set against it from the point of view of efficiency. If, on the other hand, the area is such that a larger pipe than 6 inches is needed to deal with the rain-water, it is well to have such pipes for rain-water alone, and to let the sewage proper come through smaller pipes. For these 4 or 5 inches will probably be enough, and the cost of a small iron pipe and a large stoneware or fireclay pipe may be less than that of a large iron pipe. A large sewage drain should be avoided if possible. If provision has to be made for chemical wastes, the rain-water drains form a convenient means of doing so.

General Arrangements.—The equipment of a school does not differ from that of a house, except in so far as the collecting appliances are involved. The drains are constructed on the same principles as apply to ordinary dwellings, the size being dependent on the area of playground and roof which delivers rain-water into them. Where the playgrounds are of granolithic or similar impervious surface full provision must be made for the rapid discharge which may come from a heavy shower. Where the playgrounds are of ash or similar soft surface, the rush may not be so sudden, but it is apt to be accompanied by considerable erosion of the surface, and special provision may be needed to avoid choked drains. This is specially necessary when the surface is at all steep, and is commonly made by providing sand traps of the general pattern shown in Fig. 27, p. 79.

Mischievous Interference.—To a certain extent this has always to be reckoned with. The chance of such occurring is of course greater in schools than in ordinary houses, and it may be taken for granted that any new installation will be thoroughly investigated in every possible way. One inevitable

line of investigation is that gratings are lifted if they are portable, and failing that, sticks and rubbish are poked down them. The cover shown in Fig. 25 is designed to meet this. It is possible also that miscellaneous articles may be thrown down the closets, and for this reason very full provision must be made for access to the drains. Cisterns should, if possible, be quite inaccessible by being actually built up, and not merely by height or difficulty of access. These may merely be an inducement to climb, and the supports, which would be amply sufficient to carry their intended load, might give way with the added weight of a climber. It must not be forgotten that the injury to the work may be the smallest part of the trouble. The children themselves may meet with serious accident, and while this may be due primarily to their own action, there is not only a moral but a legal responsibility connected with school construction, and the equipment ought to be of such a kind that it cannot become dangerous even when rough pranks are played with it. Whatever the equipment may be, it ought to be subjected to regular and systematic inspection.

Workshops.

The requirements of these are very varied. Generally speaking, in addition to the ordinary sanitary requirements, it may be said that the accommodation should be so arranged as to be conveniently accessible, and at the same time capable of easy supervision. When a large number of workers are employed the lavatory accommodation is under the charge of an attendant, and as the supervision of a large lavatory is as easy as that of a small one, it is economical to centralise the accommodation. On the other hand, it must be so situated that the time spent in going and coming is not excessive. In an extensive work the relative cost of two lavatories each with an attendant, or of one lavatory at a greater average distance from the users, is a matter of calculation.

Closets, urinals, and basins, are devised on the same lines as for school use. The trough closet is undesirable and should not be adopted; the greater cleanliness of the individual

closet overbalances any objection that may reasonably be urged against it.

In some classes of workshop, lavatories provided with hot as well as cold water are compulsory. Where reasonably possible they are always desirable. The school type of basin, which as a rule provides only for washing of hands (or of the face by lifting water in the hands) is not so good as an overhead supply. Fig. 91 shows in cross section a convenient type of lavatory; the water is delivered at such a height above the trough that a man can if he wishes put his head and shoulders under the stream, and this is found to be very popular. The trough is not arranged to retain water, its function is merely to receive the used water and carry it to the drain. That shown in the figure is of a size sufficient for two rows of users, one standing on each side. The water should be delivered not from a plain pipe but from a "rose" or spray, otherwise there will be trouble from splashing. A single jet of water when it strikes the surface of the trough is apt to rise unpleasantly, and unless it is divided into fine spray it is necessary to receive it on a specially-shaped surface. As in the case of school lavatories, the chief use is at fixed times, and the attendant then turns on the water to the whole range. The same arrangement as in schools is provided for occasional use.

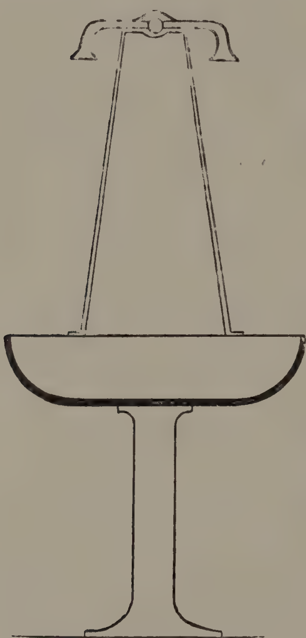

Fig. 91.—Workshop Basins.

Baths.—The provision of baths for men employed in dirty occupations is meantime an open question. It is not yet common, and it has not always been found that the men

appreciate it. Fig. 61 illustrates an arrangement adopted in a brass foundry, where it has been found that the supply has resulted in a steady demand. It has been found further that the demand is greatest at the end of the week—the old idea of a special clean up for Sunday being still in evidence.

Asylums.

Special provision is often required to meet the tendency of insane patients to stuff anything down the closets. Provision is sometimes made outside the walls to intercept anything which may have been so sent down. The provision usually consists of an intercepting chamber with a grating, through which the discharges have to pass, the whole being completely covered over but provided with an access lid. The arrangement is far from desirable, but it has been found better than the frequent choking of drains which would otherwise result. Even articles so bulky as petticoats have been carefully stuffed down the closets, and where this is likely to happen the provision of an outside interceptor may be necessary. Such interceptors when used must be examined and cleaned at short intervals. The grating is made fairly wide, so as to offer as little obstruction as possible to the proper use of the drain, but at best it is unsatisfactory and should only be adopted as a last resource.

Prisons.

The only point calling for special comment is that the closet flushing arrangements are not necessarily left to the users. It may be very undesirable to leave a prisoner with the uncontrolled use of such a convenient method of making away with anything; and to meet this, closets are arranged with the flushing handle out of reach—actuated by a warder, it may be from the outside. Otherwise the prison fittings simply conform to the usual requirements of solidity and strength, necessary wherever usage by a rough class is to be anticipated.

CHAPTER XXII

TESTS AND TESTING

Tightness.—A system of drainage should be air-tight and water-tight; and as mere observation cannot ensure this, various tests have been devised and are regularly applied. Before dealing with the special purposes for which the various tests may be used, and the conclusions to be drawn from their results, it will be convenient to consider the principles on which these tests depend, and the methods of their application.

Classes of Tests.—Tests are of two main classes. In both the test is made by introducing some substance into the system and discovering (or trying to discover) whether or not it escapes; but in the one class the test depends on catching the substance in the act of escaping, while in the other it depends on an indicator or gauge to show whether or not the substance is still there. The one class may be called "escape-detecting" tests, the other "indicator" tests.

Escape-detecting Tests.

These point out the leak to one or other of the senses, and we may have smell tests, sight tests, and tests which appeal both to smell and sight.

Smell Tests pure and simple were the earliest, but are now seldom used. A volatile and strong-smelling substance such as oil of peppermint or paraffin oil was put into the system, and a search was made through the house for the distinctive smell. One or two ounces of oil of peppermint mixed with a gallon or so of hot water, or half a gallon to a gallon of paraffin oil, was poured into the pipes by an assistant, the actual observer taking great care not to come in contact with

the material. If possible, the bottles were taken to the roof unopened, and the contents were poured down an air pipe, the assistant remaining on the roof till the search for smell was over. If this were not done, the smell might be brought in on his hands or clothes. Smell tests are also applied by passing a fragile tube through the trap of a closet, breaking it by means of an attached cord, and thus liberating its pungent contents inside the pipe.

These tests are the least searching and precise of any, but may occasionally be of service in giving a rough and ready idea of the condition of the system. Otherwise they are entirely superseded by the tests yet to be named.

Sight tests pure and simple are also unusual. The water test may be used as a sight test, by filling the system with water and looking over the pipes to see if any water oozes out; but the water test is much more effectively used as an indicator test, with its function as a sight test entirely subsidiary, and it will be described under that class.

Sight and Smell Tests.—Smoke Test.—At the present time this is the most commonly used of all, and the smoke test, which is practically the only representative of the class, is familiar to everybody. A dense and pungent cloud may be produced by means other than combustion, but in practice the use of smoke is universal.

Smoke testing is done by means of a "smoke machine." This consists of two parts, a blower and a combustion chamber. The blower is usually a bellows or a fan.

The bellows machine is shown in Fig. 92. The particular type there represented is that introduced some twenty-five years ago by Messrs. Burn & Bailie, of Edinburgh, and called the "Eclipse." It is still in very extensive use, though other makers now manufacture very similar machines. The back and forward motion of the handle A causes the rise and fall of the central diaphragm B of the bellows, and at each movement air is drawn into one of the bellows compartments and

driven out of the other. The air which is driven out passes by the tube C to the combustion chamber D, where the fuel is smouldering. From the outlet E the smoke passes to the system under test, the connection being made by metal tubes or by a hose pipe. The combustion chamber is water-jacketed, for the double purpose of controlling the heat and of forming a water joint with the lid. The lid is a copper dome like a gasholder, and its weight is so adjusted that it forms a safety valve. It rises and allows the smoke to escape at a pressure

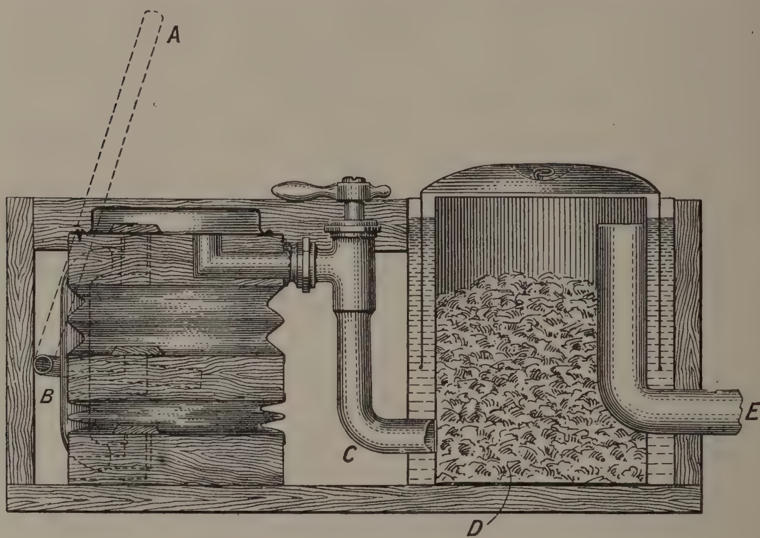

FIG. 92.—Bellows Smoke Machine.

rather less than that required to force the seal of a normal trap. This escape however can be put out of action and a higher pressure obtained when desired by a further fitting which can be had as part of the machine.

The most common fuel is oily cotton waste, though other substances such as specially prepared paper are sometimes used. What is desired is the maximum of smoke with the minimum of heat, and of course it is very undesirable that the fuel should blaze. The working of the bellows is often in the hands of boys who are not very careful, and mischief may

readily be done if the machine is connected, say, to lead pipes. The water in the jacket often boils.

The ordinary size of this machine is 20 inches by 9 inches by 9 inches, and its weight (equipped with hose, connections, and a fair supply of fuel) is about 36 lbs. In testing a large system, especially when there are considerable escapes, it may be found that this does not give sufficient volume of smoke; two machines may be used together, or a larger size of machine may be employed.

This type of machine may be used also for applying the air test, described among the "indicator" tests on p. 213. When

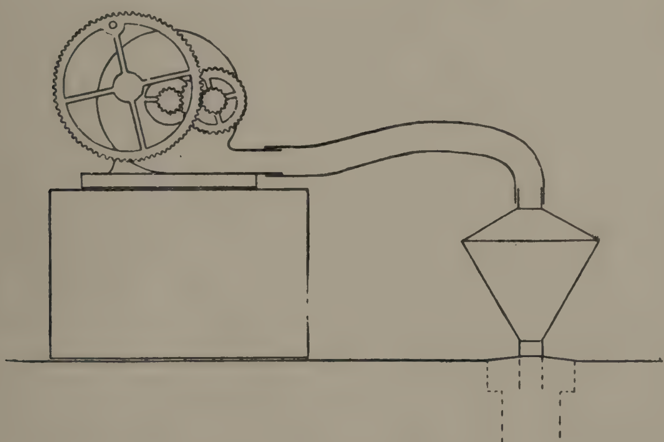

Fig. 93.—Fan Smoke Machine.

used as a smoke machine its advantages are pressure rather than a volume of smoke, and it is better adapted for testing a system that is fairly good than one which is decidedly bad. For the latter purpose the fan machine has certain advantages.

The fan machine gives less pressure, and cannot be used for air testing, but it gives a greater volume of smoke than a bellows machine of similar size and weight. On the whole, it is less generally serviceable. Many varieties have been made, a useful type being shown in Fig. 93. The centrifugal fan in this case is driven from the hand wheel by a train of gearing,

and as before the air is propelled through the combustion chamber. The gearing is somewhat noisy, but is less troublesome than the alternative method, also very common, of cord driving. The cord or belt is apt to slip or break. In the figure the combustion chamber is cone-shaped, with the flexible connection between it and the fan. This avoids passing the smoke through any tube or hose, as the cone is inserted direct into the drain. In some other makes the fan is mounted on the lid of the combustion chamber, the latter being in the form of a box in which, by reversing the lid, the fan is housed for transport. As with the bellows machine, the smoke may be delivered at a high temperature, and this must be kept in view in selecting a place to fit the machine.

In all the machines which have been mentioned, the combustion chamber is between the blower and the outlet, and the smoke in it is thus under pressure. If it is not thoroughly tight, or if the lid has to be lifted to replenish the fire, smoke escapes and causes a smell which may be confusing. Machines have been made in which the smoke is drawn from the combustion chamber through the fan, and then sent to the drain. This, however, exposes the fan and its casing to the constant passage of smoke, and the running of the fan suffers from the deposit of soot. One of the pioneer machines, the "Asphyxiator," made by Watt, of Bristol, was of this type.

"Air-pump" machines are also used, and considerable ingenuity has been shown in making machines which will be light and compact. For general work, however, it is not desirable to use a machine smaller than the ordinary size of bellows machine shown in Fig. 92. If the system is so good that a much smaller machine is sufficient to test it, then smoke-testing should be unnecessary, and the far superior air-test should be practicable.

While most smoke machines are driven by hand, some have been made in which water is the propelling power, either by the use of a small turbine to drive the fan, or of a water spray to produce the air current. The latter arrangement is extremely simple and has no moving parts, and when a connection to a half-inch pipe, with a pressure of 50 feet or

more, is available, the arrangement is convenient. It not only saves the need for a boy to drive the machine, but there is no chance of the boy taking an unobserved rest, as he sometimes

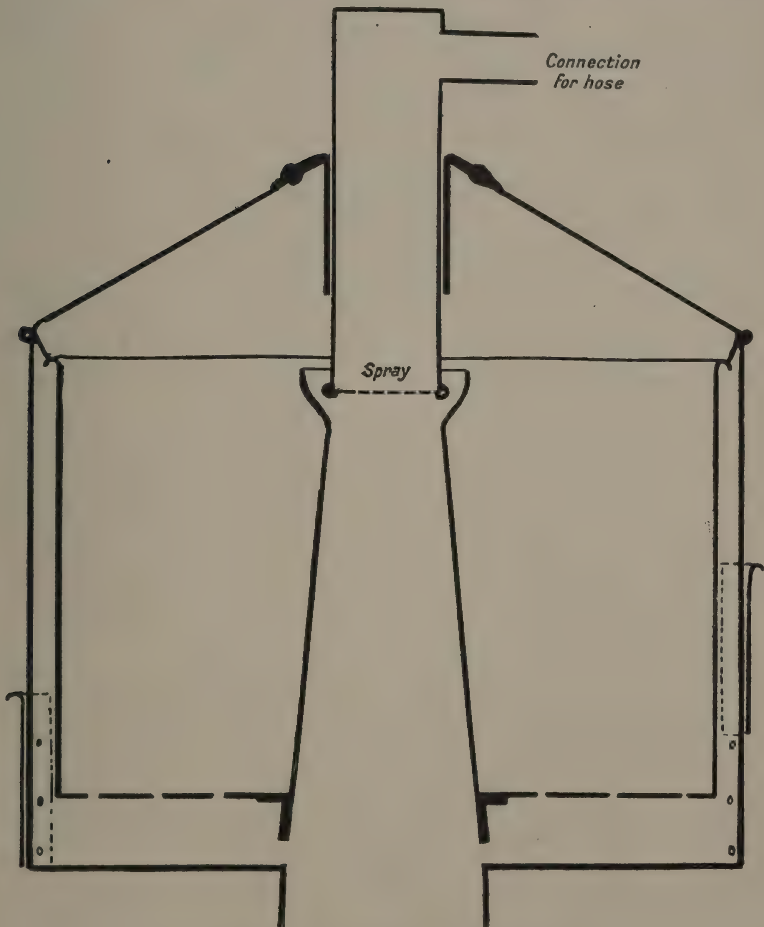

FIG. 94.—Water Spray Smoke Machine.

does at a critical part of the operation. With the water spray the smoke and water enter the drain together, and there is then no fear of high temperature. The limitations of such an apparatus are obvious, but have been overcome to some extent

by fitting a hand gear as an alternative drive to the turbine, and a fan as an alternative in the case of the water spray. Fig. 94 shows a water spray machine (designed for use with the Glasgow water pressure) with an arrangement whereby a fan can be used instead of the spray if required. The water connection and spray are in that case withdrawn, and an air pipe from a fan connected instead.

Whatever machine is used, the method of testing is substantially the same. The following description refers to smoke testing pure and simple; air testing (even when done by a smoke machine) is described later (see p. 213).

Method of Smoke Testing.—The machine is connected to the drainage system at some convenient opening. This is commonly the air inlet of the intercepting chamber or trap, or failing that the top of an air pipe. There is no reason why the test should not be as effective with the machine set on the roof; any effect due to difference of temperature is less than is often caused by natural wind currents. For ease in working and getting the smoke through the system the most important matter is to work if possible with the wind. When the machine has been fixed, the fuel is inserted and lighted with as little escape of smoke as possible. When it is smouldering and producing a free supply of smoke, the boy at the bellows or fan is instructed to work steadily but not too rapidly, and the air pipes, which so far have been left open, are closely watched. Whenever smoke in satisfactory volume is seen issuing from any pipe, that pipe is plugged (for details of plugging and connection of machine see p. 222), and when every known opening has been closed the search for leaks begins. (It is to be assumed that the system is not air-tight, otherwise an air test could and should have been used. The smoke test is used either because an air test has shown that defects exist, or because from general indications it is evident that the system is not good enough for an air test). During the search the machine is kept going, so as to maintain if possible a slight pressure in the system. Fig. 95 shows the testing machine connected to the system ready for use.

The first indication of escape is usually given by smell, and any smell of smoke is traced by the nose in the hope that the escaping smoke may be seen. If the point of escape is above ground and in a fairly accessible place, and if the leak is at all large, this will probably be the case, and this of course gives not only a clear proof that a leak exists, but shows exactly where it is. Even when the exact point is inaccessible, the

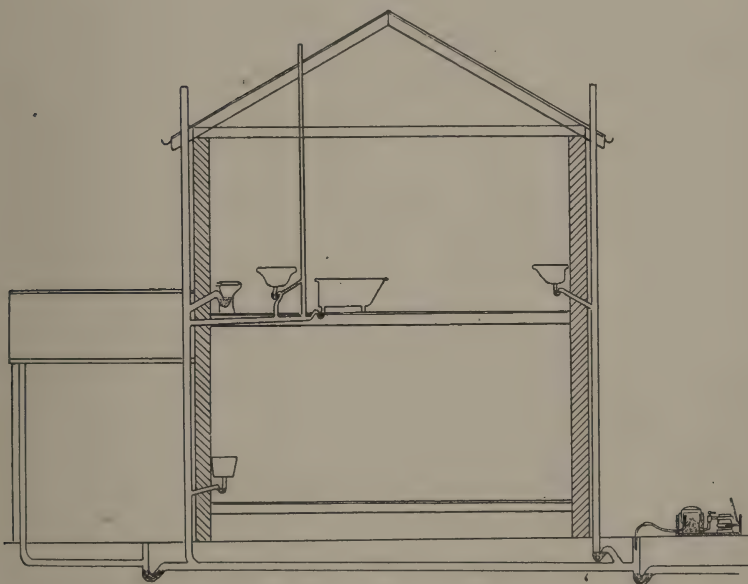

FIG. 95.—Smoke Testing.

smoke is a useful guide for exploratory opening, bearing in mind that it may have travelled a long distance before it became visible.

The danger of the smoke test is that if after careful search no indication of any leak can be found, it is often assumed that none exists. This is a most dangerous assumption. The absence of any indication of leakage may be due to many causes other than tight pipes. The main trap may be absent or ineffective, and the smoke may be mostly escaping into the

public sewer. There may be subsoil drains connected with the main drain, and the smoke may be getting through them and dissipated invisibly underground. An adjoining house has been filled with smoke when there was no appearance of leakage in the one actually under test. There are many other ways in which escaping smoke may be unobserved. It is only when the test is applied to a system of pipes which are visible throughout their whole length that the test gives any approach to certainty, and in such a case one of the indicator tests should be used. The smoke test is far superior to any mere smell test, both because of the greater pressure under which it is applied and the visible indication which it gives of an escape, but it has the same drawback that it gives no positive proof of soundness. Its great value is in locating faults known by other tests to exist, and in testing a suspected system to show whether there are any very glaring escapes. For the latter purpose great experience and skill on the part of the user are necessary, as the result of the test must be read in the light of other circumstances, and a negative result is not inconsistent with grave defects. When a system is found to leak freely the impressive nature of the proof is not without value.

Misuse of Smoke Test.—The use of this test to prove soundness is unfortunately common and cannot be too strongly condemned. To those who have no experience of more effective tests the smoke test appears excellent, and many sanitary inspectors are using it daily in blissful ignorance of its inefficiency. A report or certificate that a system of drainage "was tested by smoke and proved to be tight" is on the face of it absurd. It can only mean that no defects were found. A test under different weather conditions might give a very different result, and one man with a keen nose may detect an escape which another would overlook. The opening or shutting of a door may make all the difference between the appearance or non-appearance of smoke. The author has had so many experiences of this kind that for some years he has put a special clause into all his specifications to the effect that while the smoke test may be used by the tradesmen for their own

convenience, no regard whatever will be paid to any result or alleged result obtained by it. The above of course refers, like the general description of smoke testing, only to that test strictly so called, and not to air tests which may be made by a smoke machine fitted for that purpose.

Smoke Rockets.—Rocket cases, filled with a composition which on burning gives off a dense smoke, have been used when a more conveniently portable means of obtaining smoke was wanted. After the fuse is lighted the rocket is inserted in the drain, and the test proceeds as an ordinary smoke test. Its duration is limited to the time that the rocket burns, and its limits of usefulness are narrow.

Weather and other Influences.—Smoke testing is much affected by conditions of weather and other influences outside the control of the operator. The following considerations should be noted :—

Rain.—Rain is always a disadvantage, and sometimes a complete barrier. When rain-water is admitted directly into soil pipes or waste pipes it is not usually possible to plug these openings so as to get an effective test. When rain pipes join the drain through separate traps, the flow of water down the drain may considerably hinder the passage of smoke, and it may be that wetness may close leaks which are open under other circumstances. It requires expert knowledge and experience to decide whether any given system can be tested in wet weather with reasonable satisfaction.

Wind.—If the wind is blowing *up* the drain the tendency is for the smoke to be piled against the end where it is most wanted, and the efficacy of the test may possibly be increased. If on the other hand it is blowing *down*, the smoke is pressed to the end furthest from the house, and in such a case the value of the test is diminished. It may be entirely spoiled ; in the case of a country house with a long drain through garden ground before the main trap is reached, all the smoke may disappear through leaks in this drain, the

pipes about the house being practically untested. In most cases of this kind warning would be given by the non-appearance or feeble appearance of the smoke at some other air pipes, but this cannot always be counted on.

Temperature.—On a cold winter day, when fires are burning briskly and doors and windows are closely shut, air is rushing into the house through every chink. If some of these chinks consist of holes in the drain or soil pipe, and if a smoke test happens to be in progress, then the smoke with which these pipes are charged will pour into the house. It is urged from behind by the machine, it is pulled in front by the chimneys. If on the other hand the season is summer, when fires are few and doors and windows are open, or even in winter if the house is unoccupied, the pull of the house is gone, and the push of the machine alone remains. This means more than the actual loss of pressure ; once the smoke escapes from the pipe it is free from the effect of the machine, and may hang unobserved under floors or behind woodwork unless it is drawn into the open. Hence a test made in summer, or on an unoccupied house at any time, is much less searching (other things being equal) than a test made on an occupied house in winter. An interesting illustration of this is sometimes seen in this way : If a pipe in which there is a small leak passes through an apartment which has one door leading to the outside and another leading into the kitchen in which a good fire is burning, the smoke will sometimes appear and disappear quite regularly according as one door or the other is open, stopping when the full pressure of outside air is admitted, and becoming visible when the lower pressure of the kitchen acts upon the outside of the pipe.

Altogether, the application of the smoke test or any other escape-detecting test, is something of an exploring expedition. Whether or not any defect will be discovered depends on the efficiency of the apparatus used, the skill of the observer, the weather, and many other accidents—all in addition to the condition of the pipes. If defects are found, their existence is undoubted ; but the fact that none are found does not prove

their non-existence. The smoke test is extremely useful, but in thousands of cases it is utterly misleading.

Dodges in Smoke Testing.—If the test is not always reliable when honestly applied, it is much worse when it is deliberately "faked." When a tenant complains to the landlord or his representative about smells, it is not uncommon for the latter to send a plumber to test the drains. No doubt this is usually done in perfect good faith, but cases are known where such testing was a mere blind, its object being to keep the tenant from complaining to the sanitary authorities, and the plumber knowing well that his business was to find nothing wrong. The machine is not wrought properly, or some of the air pipes are left open so that no pressure may come on the pipes. On the other hand, a dishonest plumber may want to "make a job," and a trap may be left unsealed or forced, or the smoke may be introduced into the wrong pipe. Although such cases are no doubt rare, it is as well to remember their possibility.

Explosions.—If the burning waste contains volatile oil, such as paraffin, the drain may become charged with a mixture of oil vapour and air in explosive proportions, just as the cylinder of an oil engine is charged. Fortunately the mixture is not likely to be a powerful one—there is no compression and the resistance is not great; but the water may be blown out of traps and the cover off the machine, and the latter might cause injury to the boy in charge.

Obstructed Outlets.—The outlet of the smoke machine is apt to become foul from deposit. When a pipe of small diameter is used to connect the machine with the drain it sometimes happens that a very small passage remains open. When this is the case the efficiency of the test is seriously impaired. The connecting pipes should be frequently examined. When one is about to use a machine fitted with an indicating drum, it is well to try the effect of working the bellows rapidly before the connection to the drain is made, but after the water-lute has been filled. If the drum can be raised by this means, it shows the presence of some obstruction.

Indicator or Pressure Tests.

In these tests the testing material is introduced into the system, a pressure which would tend to force it out is applied, and an indicator shows whether or not any of the material is lost without any need for detecting it in the act of escaping. Given a material of sufficient fluidity, a pressure sufficiently strong, and an indicator sufficiently precise, the result of such a test is absolutely conclusive proof that the system is or is not tight. It being, of course, clearly understood that the test employed has a certain limit of accuracy—that is, that it will not record a loss unless it reaches a certain minimum quantity—and assuming that this accuracy is sufficient, such tests give an actual and not an inferential proof of tightness. The testing material may be either a liquid or a gas, and accordingly we have the "water test" and the "air test." These are exactly the same in principle, but the different properties of the two fluids make the practical application very different.

Water Test.—In theory this is absolutely simple. The lower end of the system is stopped, and water is run into it up to a given mark. If after a certain time the water remains at that mark it is evident that none has escaped, and that the system is tight. In practice there are a number of difficulties to be faced and precautions to be taken.

The question of plugging is dealt with on p. 222. Apart from this, the chief difficulty is that the pressure is a varying one, depending at each point on the depth of that point below the free surface of the water. If the test were applied to the whole drainage system of a building of even moderate height, where there was, say, a difference of 50 feet between the highest and lowest points, then while the pressure was nothing at the highest part it would be fully $21\frac{1}{2}$ lbs. per square inch at the lowest. As the area of a 4-inch pipe is about $12\frac{1}{2}$ square inches, the total pressure which the temporary plug has to resist is about 270 lbs. As every branch has to be plugged, the operation is one of some magnitude. The effect of this practical difficulty is that

the water test as a rule is restricted to the drain, and is not commonly applied to the vertical pipes or to the branches from individual fittings.

It is, of course, not impossible to test the pipes even of a lofty building by water. In the "sky-scraper" buildings of the United States the test is applied in sections, openings being left in the pipes at different heights, and closed after the testing is complete. The test is quite effective, except that it does not apply to these finishing connections.

Apart from the difficulty of application, the water test is an excellent one. Even when applied very roughly it gives a

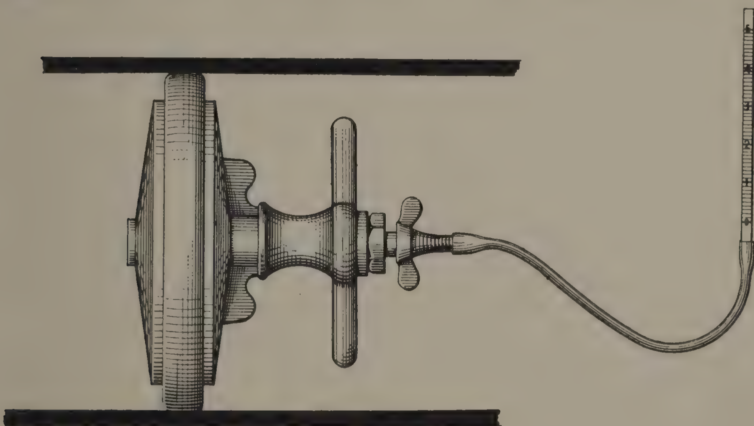

FIG. 96.—Water Test.

fairly precise indication of the character of the work, and it can be made a test of great delicacy. If the free surface of the water is of small area, which can be ensured by having a small tube at the upper end, a very slight loss is readily noticed. This application is shown in Fig. 96. Water is practically incompressible, so that the total quantity which escapes is accurately recorded on the tube. It may sometimes be necessary to make an allowance for the absorption of water by jointing material, but if a fall in the gauge is due to absorption, it will only continue for a limited time.

For high pressures this is the only test which can safely be applied, and when it is necessary to use a test pressure

exceeding 2 or 3 lbs. per square inch, it is the one which should invariably be adopted. The incompressibility of water prevents work being stored up in compressing it, as happens in the case of air. If air-pressure up to anything like 20 lbs. per square inch were used the risk of explosion would be a serious one. The risk of damaging the pipe is a different thing, and the water test should never be applied unless when every part of the pipe is visible, or failing that, when it is clearly understood that the test may involve exposing it completely and perhaps renewing it.

The question whether sanitary authorities should apply this test as a systematic part of their inspections has been much discussed. No one challenges the propriety of applying it to new drains, constructed in expectation of it; but while in theory every drain ought to be fit to stand it, it would be a somewhat high-handed proceeding to apply it to all drains indiscriminately. There are many drains whose condition is no menace to health, which would fail to stand the water test, and which under the process would be made much worse than they are.

The water test can only be applied to a system or part of a system which is for the time entirely out of use. All water except that which is put in for the purpose of the test must be kept out, and dry weather is thus often an essential. It is always desirable.

If on the application of the water test it is seen that no escape is taking place, nothing remains to be done; the test is complete and entirely satisfactory. If on the other hand it appears that there is some loss, the next thing is to locate the leak. If it is a large one the escaping water reveals it at once. If all the surroundings are thoroughly dry, even a small leak may be found without much difficulty, though the search may take some time. The smaller the leak the more difficult it is to find, and as only a slight dampness may in some cases show on the outside, a somewhat careful search is necessary. In wet weather, or in the case of a drain laid in a wet trench, a small leak may readily be overlooked.

It will be seen that the water test is used first as an

"indicator" test, to prove that the system is or is not tight. Failing a satisfactory result, the test is used as an escape-detecting test to locate the fault by sight. If the test is used with a large free surface of water, as is often done, its delicacy

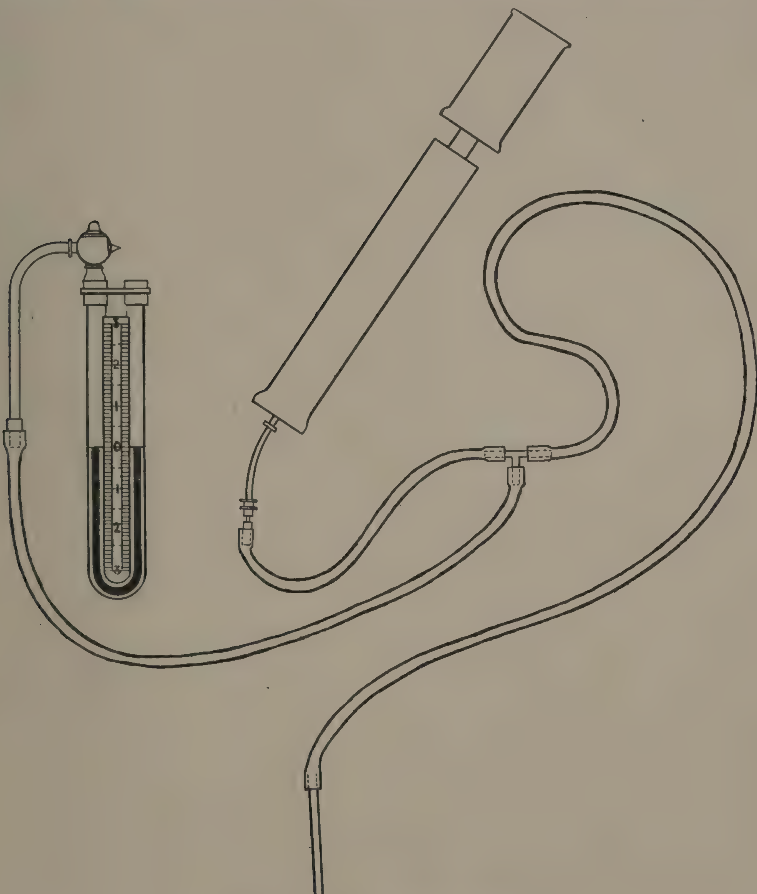

FIG. 97.—Air Test Apparatus.

is much diminished, but it is still immeasurably superior to the smoke test.

Air Test.—In practice, this is the simplest of all tests, and the apparatus required is only an air-pump and a gauge. A

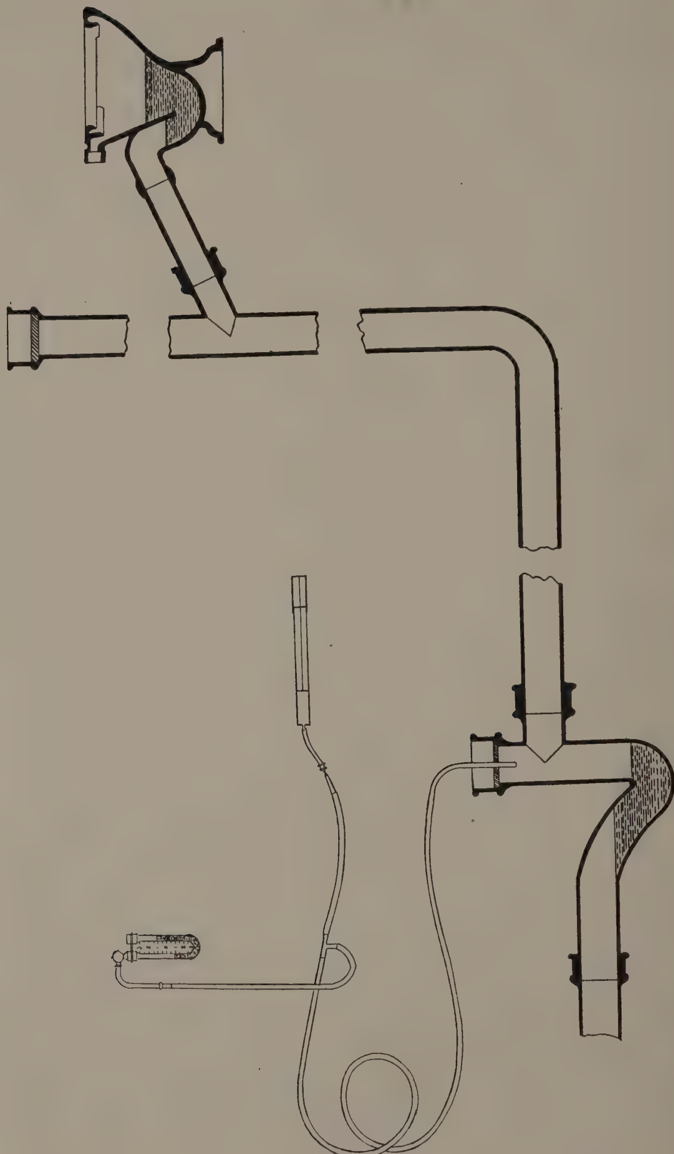

FIG. 98.—Air Test Applied.

simple but efficient combination is shown in Fig. 97. The air-pump is an ordinary bicycle inflator, and the gauge an

ordinary gasfitter's gauge (in scientific language a "manometer") consisting of a U-tube fitted with a scale. The connections are made by rubber tube, $\frac{1}{4}$ inch in diameter. A bicycle valve, as shown, is convenient, but a stop-cock serves the purpose quite well. For convenience in making connections the delivery end of the rubber tube is fitted with a few inches of brass tube, so as to give a non-compressible end.

The test may be limited to working pressure, in which case only the air pipes and other open ends have to be plugged; or it may be used at higher pressures, in which case all traps require also to be plugged. Fig. 98 shows the operation under working pressure, and the method is as follows: Water is put into the gauge glass up to the zero mark, the level in each of the two legs of the tube being, of course, the same. The apparatus itself may be tested by dropping the delivery end of the tube into a pail of water. This compresses the air, but the total amount of air so compressed is so small that a very small leak instantly affects the pressure, and a few seconds are sufficient to show whether or not everything about the apparatus is tight. This preliminary test is useful when subsequent faults are found in the drainage system, as it disposes of any suggestion that the apparatus is at fault. The end of the tube is then connected to the system to be tested either by an air bag or expanding plug (Figs. 100 and 101), or by means of puddle clay; all air pipes and other openings are closed, and air is pumped in. As the pumping proceeds, the water in the gauge should register a gradually increasing pressure. When the desired pressure has been reached the pumping is stopped. After an interval the reading of the gauge is again noted, and the initial pressure, the final pressure, and the interval of time, are all recorded. Three minutes is a fair time interval for any ordinary system, but as it is proportional and not absolute loss that is indicated (see p. 217) the time should be more or less proportioned to the capacity of the system under test. If the final reading, after the lapse of an adequate time, does not differ from the initial reading, the test is satisfactory, the loss, if any, being so small that it cannot be detected. The possible effect of change of

temperature (p. 219) or of the entrance of water to the pipes (p. 221) may have to be remembered.

When the test is applied as above, the resisting power of the weakest trap is incidentally measured. Whenever the pressure exceeds that which the weakest trap will stand the air bubbles through that trap, and the gauge will rise no higher. This is usually taken as the test pressure. If, however, one trap were thus found to be abnormally weak, it might be well to plug it and continue the pumping till the limit of the next weakest had been reached. The trap which naturally gives way first is that (if any such is included in the test) upon which the pressure comes from above downward. Referring again to Fig. 98, it will be seen that when the pressure comes on the disconnecting trap, it comes on the upper side, and the displaced water flows away. At the closet trap, on the other hand, the pressure is on the lower side, and the displaced water is banked up above the trap. If the two traps have the same depth of seal, the resistance of the one will be approximately double that of the other. Thus while in the figure the lower trap is on the point of giving way, the upper (of the same normal depth and under the same pressure) has still a considerable power of resistance (compare p. 57).

This test can readily be applied to the drainage system of an occupied house, but it is sometimes difficult to prevent water being run into the pipes from time to time by the use of the fittings. If this cannot be done, an exact test is impossible; but if a gauge connected in the manner described fluctuates with the passage of water through the pipes, it shows that if any leak exists it cannot be a big one. An approximate test can thus be got under conditions in which any other test would be useless. With some care and patience, however, it is usually possible to get a short period free from any such disturbance, and every effort should be made to do so. It must be remembered that the use of any of the fittings during the time that the air pipes are closed may cause partial or complete syphoning of traps; and when the gauge cannot be got to show a pressure of more than half an inch or an

inch of water, but remains steady at the low pressure, partial syphoning is often the explanation.

In smoke testing all the air in the system has to be expelled and replaced by smoke; in air testing all that has to be done is to add to the air already in the pipes the trifling amount needed to produce the pressure. A pressure of 4 inches of water is only about one-hundredth part of an atmosphere, and the extra air required is thus only the hundredth part of the total capacity of the pipes. Hence the possibility and the consequent convenience of using such a small pump as that shown in the figure. The whole of the apparatus required for this test can be carried in a hand-bag, or even in a large pocket.

When a pressure beyond the ordinary working pressure is required, mercury may be used in the tube instead of water. With a 6-inch tube any pressure up to about 3 lbs. per square inch can thus be applied, and this is quite as high as is desirable in air testing. The plugging requires to be much stronger to resist the high pressure; all the traps must be specially plugged, and the amount of air to be pumped in is considerably greater. It is found in practice that pipes which will stand the light pressure are not likely to fail under the higher. With the materials now in use it is not weakness that is to be guarded against so much as flaws, and a pinhole in a pipe, a porous solder joint, or a badly caulked lead joint, is promptly detected by a very trifling pressure.

Instead of the U-tube, a pressure gauge of the Bourdon type might be used, but the simpler form has many advantages. At the low range of pressures which is usually needed it is much more sensitive, and its cheapness is an obvious recommendation.

Proportionate Loss Shown, not Absolute.—Any form of pressure gauge, when dealing with a compressible fluid, indicates proportionate and not absolute loss. If a pressure of 4 inches of water is shown, the pipes contain 1 per cent. of extra air; if that pressure falls to 2 inches, one half of that air has escaped. Whether that is a large or a small quantity depends upon the size of the system. If the total capacity of

the system were 100 cubic feet, then the pressure of 4 inches would be produced by forcing in 1 cubic foot and the drop to 2 inches would be caused by the escape of half a cubic foot. If the total capacity were only 10 cubic feet, then the same drop of pressure from 4 to 2 inches would be caused by the escape of one-twentieth of a cubic foot. It is evident that the test is more searching the smaller the system, hence the recommendation already given that the time of test should have relation to the total capacity. When it is remembered that it takes about 12 lineal feet of 4-inch pipe to contain 1 cubic foot of air, and that in a system containing 100 cubic feet of air, 1 extra cubic foot would raise the pressure to 4 inches of water; and, further, that on the gauge one-tenth of an inch can easily be read; and that this on such a system is equivalent to one-fortieth of a cube foot of air: it will be seen that even on a large system the test is a delicate one.

Testing by Air to Fixed Pressure.—If great delicacy at a specified pressure is required this can be got by using as an indicator a floating drum of small capacity say an inch or so in diameter (Fig. 99). By this arrangement the indication is not spread all over the scale of pressure, as with the ordinary gauge, but is concentrated into one part. The drum is a miniature of that used in the Eclipse smoke machine, and its size and weight are so proportioned that it remains on its seat until a certain pressure—say 2 inches of water—is reached. A very slight increase then causes it to rise, and the increase in total capacity caused by the rise of a small drum is trifling. The whole rise therefore takes place under a very slight increase of pressure, and the indication approaches in delicacy that given by a water test in a small tube. By combining this with the manometer, a continuous reading can be got from the one and a sudden and large indication from the other. The water in the U-tube moves gradually as the pressure increases; the drum does not rise until the pre-determined pressure is reached, when it rises suddenly. It is not difficult, however, to get fully satisfactory

results from the manometer alone. The ordinary Eclipse machine is often used as an indicator. Its drum being of considerable capacity, the indications are not so delicate as with a small drum, but if its drum remains stationary for a few minutes the test may in any ordinary case be regarded as quite satisfactory.

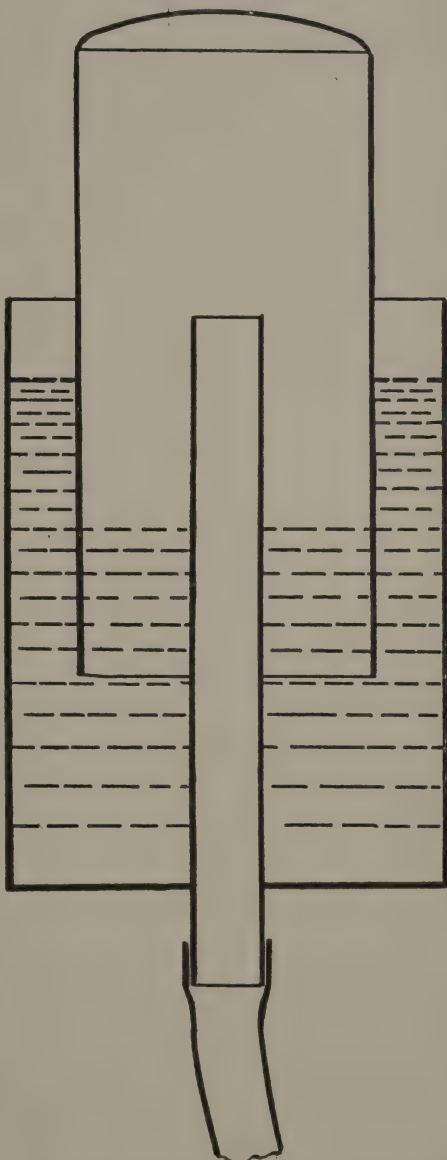

Fig. 99.—Small Drum for Air Testing.

Gauge Records. — The use of the gauge has the advantage of greater range, and it is convenient to record in tabular form the result got at any time. Interesting and valuable comparisons with future results are thus possible.

Effect of Temperature.—When air testing is done alone this need not be considered, as any increase of temperature due to compression in the pump is negligible. But as smoke

testing implies blowing hot air (or smoke) in considerable volume into the system, there would be a loss of pressure due to its cooling, quite apart from any escape. If, therefore, an air test is made by the use of a smoke machine it should be done without lighting the fire. If for any reason both tests are applied the air test should come first. The expansion and contraction due to atmospheric or other changes do not as a rule cause any inconvenience, but this possibility should not be overlooked.

Result of Air Test.—Four results are possible :

(1) The gauge may rise to the required pressure and stay there for the required time. That is, the test is entirely satisfactory.

(2) The gauge may show some pressure but not retain it.

(3) The gauge may not rise at all.

(4) The gauge may show a fluctuating pressure.

If the gauge falls it indicates a leak. If the pump used is a small one, the fact of the gauge rising at all shows that the leak must be small. The leak is not located by any visible sign, and may not be easily found. The following methods may be used :

If the system is of some size, remove an access cover so as to let it be tested in two or more parts. Any part which is found faulty is again subdivided, until the leak has been traced to the smallest available section. It may then, perhaps, be located by the smoke test, but the air test is so delicate that it will indicate a leak which the smoke test may fail to discover, even when applied to a small section with the knowledge that the leak is there. It may be well to recaulk all the joints in that section and again apply the air test. Another method is to paint the joints of the faulty section with a strong solution of soap, through which the escaping air will bubble, while when testing to a high pressure the leaks are often traced by the sound of the escaping air. A drain laid in a wet trench may be tested even if it is completely submerged—a sufficient pressure being used—and leaks in such a case are very clearly indicated by the bubbles. While the joints are always the

most likely parts to be at fault, it is not impossible that the pipes themselves may be leaky; this danger may be avoided by the use of previously tested pipes.

When the gauge will not rise at all, the leak is of unknown size, and may be big enough to be found readily by smoke. Quite frequently the plugging of some air pipe has been overlooked; sometimes the plumber has forgotten to make some joint; a trap may have been left empty, or a trap may have been emptied by syphonage. Otherwise the methods of locating the leak are similar to those just described. The larger the pump or bellows used, the less likely is this negative result to be reached; the use of a larger pump merely means that a result of a sort may be got from inferior work. A small bicycle pump is sufficient to differentiate between good and fair work; a larger one will give a distinction between fair and poor work. A fluctuating pressure is due to water entering the system. If a body of water enters a closed system of pipes, the air pressure is raised and some of the air probably is forced through the traps. If the water can escape through a trap, the air pressure is reduced and may become negative—the pressure inside being less than the atmospheric pressure. A series of such fluctuations is sufficient to prove that there is no large leak, and in the case of an occupied building it sometimes happens that nothing better can be got.

Dodges in Water and Air Testing.—The water test may be dodged by putting in extra plugs. The drain may have a plug at its low end, and appear to be filled with water, while a second plug has been fixed near the top. Where there is any chance of such a trick, the filling or the emptying should be done under supervision. In air testing there is less room for trickery, as there is no certainty as to the point where the test may be applied, and the pumping is naturally done by, or in presence of, the man who makes the test. An operator of any experience would notice at once if the actual capacity of the part tested was much below the apparent capacity, by the small amount of pumping required;

but it is in any case a proper precaution to order the removal of a distant plug, selected without previous notice, after the gauge or indicator has remained steady for the required time. The removal of the plug should, of course, bring it at once to zero. It has been suggested that if the test is always made at the pressure given by the weakest trap, anyone who knew this might arrange to have a second pump out of sight engaged in keeping up the pressure. A test at a lower pressure would at once bring this trick to light, and altogether, so much skill and trouble are required for even a hopeful attempt to dodge the air test, that it is not very often tried.

Plugs for Testing.—Testing involves closing the ordinary openings—the lower openings only in the case of water, and all openings in the case of air or smoke. In the latter case, if the test pressure is not to exceed the resistance of the traps, and if the traps are all in place, they themselves serve as plugs—care being taken that they are properly filled. In other cases the traps themselves, or the branches which are to receive them, must be plugged. The method of plugging depends on circumstances.

In an ordinary smoke test there is no difficulty, and while special appliances may be convenient, a supply of fairly good clay will meet all actual needs. The machine may be connected to the drain by a lead or zinc flange, or even a flange made of slates, packed with clay. The air pipes may be closed with a plug of cotton waste or of paper, again coated with clay. It is sometimes not even essential that these should be air-tight: a slight escape keeps the smoke in the pipes fresh, and at the same time shows that the machine is working properly, but the plugs should always be nearly air-tight, or the loss of pressure may be prejudicial.

For an air test the plugs must be really air-tight, but if the pressure is not to exceed the working pressure, *good* clay is still quite satisfactory. There is no more effective plug than a tight packing of waste in the socket of a vertical pipe, covered with clay at such a depth as to hold an inch or two of water over it. Any escape is at once noticed.

When a job is in progress at which frequent testing will be needed, it may be worth while to have a number of wooden plugs, say about six inches long, kept in readiness. These are cut to a slight taper and painted, and when faced on the inside with good clay, and driven hard into the pipe, are serviceable even when fairly high pressures are used. They do not cost much, and a number may be readily provided.

In many cases, and especially where portability is of consequence, air bags and expanding plugs are of considerable service.

Air Bags are made of some air-tight material, provided with a tube and stop-cock, In their simplest form they are mere

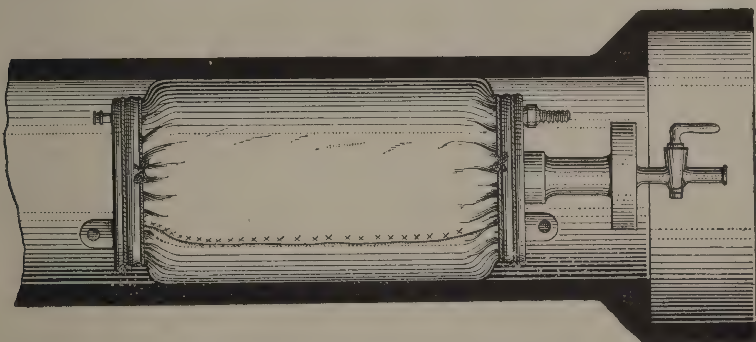

Fig. 100.—Air Bag as Pipe Stopper.

bladders, but they are often more elaborately fitted. That shown in Fig. 100, for instance, has two interchangeable ends—either of which may be used for inflating—and it has a tube right through for the introduction of the testing material. The inside rubber bladder has a wide range of expansion, but it is enclosed in a canvas bag to suit the size of the particular pipe to be stopped. These stoppers are inflated after they have been put into the pipe, and they may be put into, or even passed beyond, traps when it is desired to plug these.

Expanding Plugs are more suitable when high pressures are to be resisted, and especially for use with the water test. They consist essentially of a rubber ring held between two discs. These discs have bevelled edges, which force the rubber ring

outward when they are brought tightly together. The apparatus is of such size that with the discs loose, and the rubber of its natural size, it will slip freely into the pipe which it is designed to close. The discs are then brought together by a screw, and the rubber ring is thus forced into hard contact with the inside of the pipe and with the discs. Instead of a plain screw, a screwed tube of any required size may be used, and this gives a connection for smoke machine, indicator, or air pump, or for the introduction or the withdrawal of water. Fig. 101 shows a plain plug slack and tight. A similar plug with a glass tube connected to it for use with water test is shown in Fig. 96. These plugs are made by numerous makers, with variations in detail but with the same general

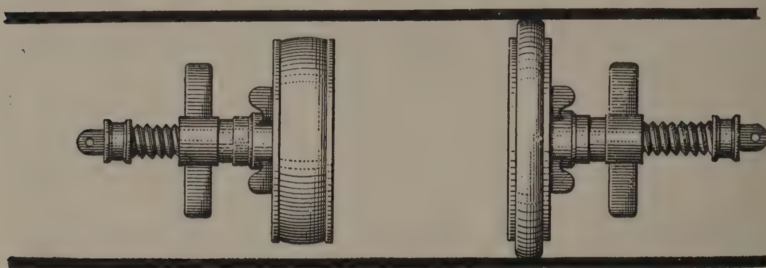

FIG. 101.—Expanding Plugs, Slack and Tight.

idea. They are made in iron, brass, and aluminium, and the lightness of the last named is of some value when a number have to be carried. They are also made in various sizes, and by varying the rubber rings the same pair of discs may be used for two or three slightly different sizes of pipes.

Comparison of Tests.—For all purposes where certainty is required, the water or air test should be used. Of these the latter is much simpler, and air is so much more ready to pass a minute opening than water is, that a low air pressure is a more severe test of tightness than a high water pressure. On the other hand, if *strength* is to be proved, the water test is best, and is the only test which should be used when a pressure of more than two or three pounds per square inch is required.

As a rule, the danger is not so much weakness as want of tightness, and the air test is the best for detecting the latter.

Sometimes the water test is applied to the underground drains, but not to the other parts of the system : the reason being that in the event of an accidental stoppage the underground drains might be subjected to severe pressure. There is no objection to this, except that it is scarcely necessary ; for if a drain constructed of modern materials is proved to be tight, there is little doubt about it being strong enough. In such a case the air test should be applied to the rest of the system, not smoke.

The air test has the advantage over water in the rapidity of its indications. The plugging and pumping do not take long, and it is never necessary to wait more than a few minutes after the gauge has been first read. Water testing, when plugging, filling, and emptying are taken into account, is a much longer operation.

Even as compared with smoke testing, air testing is much more expeditious, as the time which is needed to go over the whole system searching for possible leaks is replaced by the few minutes that the gauge is under observation, and the time required to charge the system with smoke is also saved.

The author has for the last ten years depended chiefly on air testing for work carried out under his supervision, and has been entirely satisfied with the result. It is not popular among those who wish to get off easily with inferior work, and it has brought confusion to many an honest tradesman who did not realise in time the extreme delicacy of the test; but one experience of the test is usually sufficient to ensure a high standard of work in the future. It is admirably adapted to the requirements of the engineer who has to see that his specification has been met, and of the sanitary official who has to prevent the construction of inferior work. The responsibility of producing good work rests on the tradesman, and all that the engineer or the official has to do is to prove whether or not this has been done, and to pass or condemn the work accordingly.

There is still an important field for smoke testing, and this will continue until air-tightness is required in all systems old or new. When an investigation has to be made as to the

sanitary condition of the average house, the smoke test is applied as a matter of course. By no other means can information be so readily got, and when properly used it is of the greatest value. It may reveal improper connections, or pipes in unexpected places; and it may show that leaks which render an air test impossible are only in trap shafts or other places of minor importance. When a system is really bad, the escape of dense volumes of smoke is often useful as a means of carrying conviction to the mind of a sceptical proprietor. On the other hand, the non-appearance of smoke is often regarded as proof that a system is perfect, and this is a most dangerous mistake. It is quite common to have the negative result of a smoke test put forward as a conclusive proof of good drainage: and in this respect the smoke test is a serious hindrance to sanitary progress. In reporting that the smoke test was applied without revealing any defects, it should be an invariable rule to add that this is no proof that no defects exist.

What Pipes to Test.—Pipes are occasionally left untested on the ground that "they are only waste pipes." Waste pipes should be tested even when they are trapped off from the main drain, and should, like the rest, be air-tight. On the other hand, there is as a rule no occasion to test rain pipes, which are not expected to be air-tight, and from the top of which gases can in any case readily enter the house. Rain pipes should be kept entirely by themselves and trapped independently, but in old work they are often found combined with waste pipes. In that case it may not be possible to test the latter satisfactorily.

Tests for Straightness and Clearness.

It is usually specified that drains are to be laid in straight lines, no bends being permitted except at the manholes, where inspection bends give access to the inside of the pipes. This method of construction makes it possible to see through the inside of the pipe not only while the work is in progress but at any time thereafter. This is done by the use of a mirror at one end of the stretch to be inspected, and if

necessary, a lamp or candle at the other. Straightness is proved by the fact that a full disc of light can be seen: if the pipe is not straight, the disc is not round but partially eclipsed. Clearness is easily proved; with a little practice one can note every joint on a moderate length of drain, and detect if any jointing material or other obstruction has entered. Sometimes loops of yarn, or ends of hemp, or molten lead, find their way into the bore of the pipe; and any of these might form a nucleus for a serious choke. Sometimes the obstruction is of a more determined kind: in the author's own experience a disc of slate and a disc of lead—each put into the socket over night by a careful tradesman, and forgotten in the morning—have been found. While a small lamp and a small circular mirror may be convenient, the necessary equipment for this test may be readily extemporised, and a plumber's candle (if the daylight is insufficient) at one end of the line, and a bit of broken looking-glass at the other, often serve the purpose. A small electric lamp on a carriage, which is pushed along the drain by rods, has been devised as an aid for such inspection, but this introduces great elaboration into what, as a rule, should be a very simple test.

CHAPTER XXIII

SANITARY INSPECTIONS

A REPORT is wanted on the sanitary condition of a building. The information required must be got by examination, and it should be got with the least expenditure of time and effort, the least disturbance of structure or of ground, and (in the case of an occupied building) the least inconvenience to the occupants.

Scope of Inspection.—Very often the examination is limited to the arrangements for drainage and water supply. If not, the additional points are:—the dryness or otherwise of the walls; the presence or absence of protection from ground dampness; the condition of the roof, gutters, and rain pipes; and (in poorer class houses) the condition of plaster, windows, etc. Sometimes, also, it may be important to ascertain the cubic capacity of rooms and compare this with the number of occupants: to examine the provision for ventilation, and even to look into questions of heating and lighting. In densely peopled districts the surface of courts and the position of ash-pits are of importance, and the crowding of houses on a limited space may of itself be such as to cause insanitary conditions.

With regard to drainage and water supply, a systematic investigation is made as follows:—

Plan.—Ascertain if any plans are available. If an accurate drain plan is to be had, much time will be saved; failing this, a ground plan even without drains is of value. If either of these can be got in advance, it is convenient before going to the place to prepare a rough tracing, on which notes and corrections may be jotted during the examination. If no

plan of any sort is available, a sketch plan should be made on the spot, and it is usually worth while to take measurements sufficient for subsequently laying down to scale a block plan at least. The points of the compass should always be noted.

After making a general survey of the building and surroundings, and noting, if possible, the line of drains, it is useful to go on the roof. This affords a good "bird's eye view," and may give valuable information about the position of soil pipes and waste pipes, if these are carried up as ventilators.

Assistance and Information.—Assistance is required for making any openings that may be wanted, for manipulating the testing apparatus, for closing air pipes for test, and the like. If practicable, it is well to be assisted by men who are familiar with the place. A plumber who is in the habit of working about the pipes should have a fair knowledge of their ramifications; while about a country house there is usually someone whose duty it is to keep traps clean, and who may know a good deal about the drains. Information of considerable value may be got in this way, but it is well to remark (1) that such information may be given in good faith but inaccurately, and (2) that it is not impossible that deliberately misleading information be given. Everything, therefore, should be verified before being finally accepted.

It should also be borne in mind that while men may be instructed by their employers to give what assistance and information they can, this may or may not be given with goodwill. If they see that any information which they give is accepted as a matter of course and without thanks, the information given is apt to be very limited. If, on the other hand, they see that any assistance beyond the letter of their employment is regarded as a favour and courteously acknowledged, it is usually given very willingly.

Outlet.—If, as often happens, no information is available, except what can be got from actual investigation, the first

thing to look for is the place (or places) where the drainage leaves the premises. In a modern system that is the main intercepting trap (or traps). The position of the various soil and waste pipes is ascertained and marked on the plan, and the lines of drain which connect these sources of sewage with the outgo have next to be filled in, and this is commonly done by tracing the flow of water down the drain. Water is introduced at some known point, and its appearance at lower points is watched for. Various trials may be necessary to eliminate the chance that the flow is due to the casual use of another fitting, and sometimes the use of water coloured with ochre, whiting, and the like, is useful. The smoke testing machine also may be used with advantage, the passage of smoke from point to point indicating a drain connection. Ultimately it should be possible to sketch with considerable accuracy the connections, if not the exact routes, of the various pipes. Any manholes will, of course, be opened, but when there is a closed pipe at the foot of the manhole (as in Fig. 37) discretion will be exercised as to whether or not the lower cover should be disturbed.

Tracing the flow through traps is easy when the traps are of the modern ventilating type. When they are like those in Fig. 20, it is far from easy to detect the flow. But when traps such as these are found, there need be little hesitation in reporting that an extensive overhaul is needed, and the precise condition of the existing drainage is of little moment.

Tracing Connections.—The general drain plan being known, and the position of the various vertical pipes ascertained, the next thing is to trace each of these pipes and its connections. This may be conveniently recorded by lettering or numbering each vertical pipe on the plan, and drawing a diagram section of each of these pipes. Fig. 102 illustrates a note-book page recording this information. In an old-fashioned house where pipes are concealed, it is not always easy to trace the flow. Sometimes it may be necessary to trust to the sense of hearing, and to listen for the sound of

water in a soil or waste pipe, when water is running in the fitting in question.

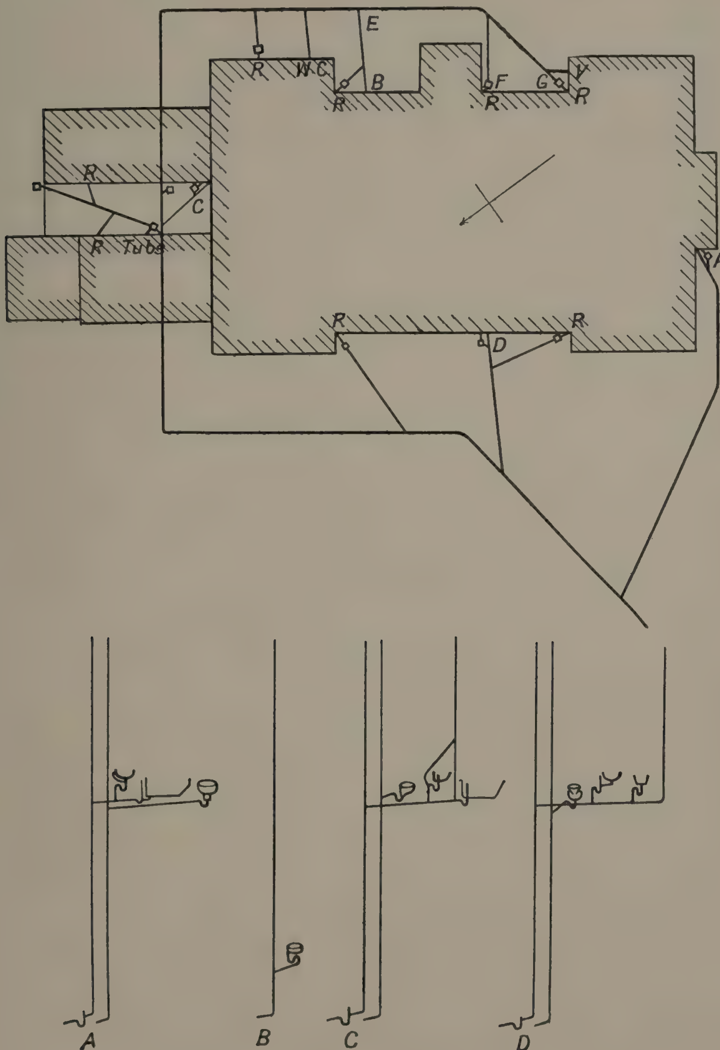

FIG. 102.—Note-book Sketches.

Details of Fittings.—All details of fittings should be noted. It is not sufficient, for example, to note that there is a closet

or a bath: the note should specify the kind, the condition, and any other particulars which may be of service. A closet might be a wash-down closet with S or P trap; with a putty joint inaccessible, a putty joint accessible, a flange joint, or a metallo-keramic joint. It might be supplied from a high or a low cistern; it might stand open, or wholly or partly boxed in. Conventional signs may be used to indicate some of this information on the sketch, *e.g.*, in Fig. 103, a Bramah closet is shown on pipe A, a washout on B, a washdown on C, a pan on D. The bath and basin on A have old overflow arrangements, while those on C have hollow plugs. Other information may be written on. With the old type of fittings, such as a Bramah closet, the questions of safe, safe pipe, cistern, trap ventilation, have all to be remembered: and in doubtful cases it may be necessary to test whether or not the closet syphons its own or any other trap (see p. 161). Cistern overflow pipes, unless they discharge visibly, are always to be regarded with suspicion, and their ending traced.

The material of which the pipes are made, and the quality (including thickness) of that material, should be investigated. The chief defects to be looked for in this connection are that "light" iron pipes, or lead pipes so thin as to be readily damaged, may be used. The jointing of the pipes should be noted, to see whether all solder joints are wiped, and all joints on iron pipes run with lead: and whether or not brass ferrules are used. It does not necessarily follow that the work is to be condemned because it does not in every respect reach the standard of first-class work; and while all defects, large or small, should be noted, a careful discrimination must be exercised in afterwards reporting so as to have the relative importance of these clearly brought out.

Testing has already been discussed in detail in Chap. XXII. For an exploratory investigation a smoke testing machine is essential, because it is not only valuable as an indicator of leakage, but it is often a most convenient means of discovering the course and termination of the pipes belonging to some

special section. When the system is obviously leaky, its value in convincing a sceptical owner is not to be overlooked, and, even if the system is so good that it may be tested by air pressure, the smoke machine is convenient as a stand-by. An air-test often fails to give any result because some air pipe has inadvertently been left open, and the smoke test is the most convenient way of discovering the omission.

When the smoke test is used to trace the ramifications of a system, and to discover whether one part is directly connected with another or is trapped off from it, it is generally safe to assume that the passage of smoke negatives the existence of a trap. (It is just possible that an ineffective trap may exist: the pipe may be so leaky that smoke gets out of it on one side of the trap and in again on the other.) The non-appearance of smoke proves little; it may mean that there is an intermediate trap, or it may mean that there are so many escapes that the smoke is lost through the ground. The warning already given—that under no circumstances can the smoke test warrant the statement that the system has been proved to be tight—may be repeated—unless of course the smoke has been used as a pressure test.

It happens not infrequently that during the test some traps are syphoned, owing to water being discharged while the air pipes are stopped. It is very desirable to stop entirely the use of the fittings during the test. If this is impracticable, there is often doubt as to whether the smoke which has escaped has come through some actual defect, or through some trap which has failed merely owing to the exceptional circumstances. With modern fittings and good ventilation syphonage in other circumstances is not to be expected, but it may be necessary sometimes to make sure that a Bramah closet does not syphon its own trap. To do this it is best to disconnect the water supply from the valve lever, so that the supply and the discharge can be operated independently. The closet basin is then filled up to the overflow level and the water allowed to come to rest: the valve is smartly opened, and the presence or absence of the very characteristic "gurgle" noted. If there is no gurgle, no

further trial is needed; but if the sound is heard, then the actual depth of water in the trap after the trial should be measured and compared with the depth when the trap is filled by slowly running water through it. A further test is to drive a nail partly into some long piece of wood, such as a broom handle, the nail projecting at right angles from the stick about an inch from its end. The head of the nail is then allowed to slide gently down the inside of the pipe on the side toward the bend, until it passes under the bend. The distance upward from the nail to the water surface, indicated by the wet mark on the stick, is the measure of the seal which remains. The depth, if there is no syphonage, should be $1\frac{1}{2}$ or 2 inches.

Water Supply.—On a large scale water supply is entirely distinct from drainage, but in the fittings of a house the two come into close contact, and an inspection of the drainage arrangements which took no notice of the water supply would be incomplete. The greatest danger indeed is that the association may be too close.

Public Supplies.—In houses which are fitted with modern equipment, and supplied with water by a corporation or company whose regulations are up to date, there is little to be feared. The service will be a "constant" one, and there will be no cisterns except the flushing cisterns of the closets, and a larger cistern to regulate the supply to the hot water system. If there is a separate hot water system of heating, it also will have a small cistern. In every case the overflow pipe of the cistern will discharge visibly, thereby making it impossible that it may connect direct with the drain system, and no emptying taps (see p. 235) will exist unless they, too, discharge visibly. All the cold water for supply purposes will be drawn direct from the main. It may usually be assumed that the quality of the water supplied in this public way is satisfactory, and that its action on lead is negligible; if not, then the matter is not one for the individual householder.

Private or other Uncontrolled Supplies.—When the fittings are not controlled as above, either because the supply is a private one, because the supplying authority is not up to date, or because the equipment is older than the regulations, it becomes necessary to make a more complete investigation directed specially to the following points:—

1. *Cisterns.*—These may be badly situated, and may be dirty. They may allow the water to absorb foul gases, or they may be exposed to pollution by vermin, birds, &c. They may have overflow pipes connected with the drainage system, either with no attempt to keep the drain-gases from reaching the water, or with an unsatisfactory attempt to do so. No such connection is ever satisfactory. The very fact that water for drinking and cooking purposes comes from a storage cistern in the house is bad, and should not be tolerated unless it is impossible to do otherwise, and then only under very stringent precautions. It is well known that water improves by storage in a large reservoir, but storage in a domestic cistern is a very different thing. Any improvement due to sedimentation is far more than counterbalanced by the absorption of injurious gases, to say nothing of the chance of solid or liquid contamination.

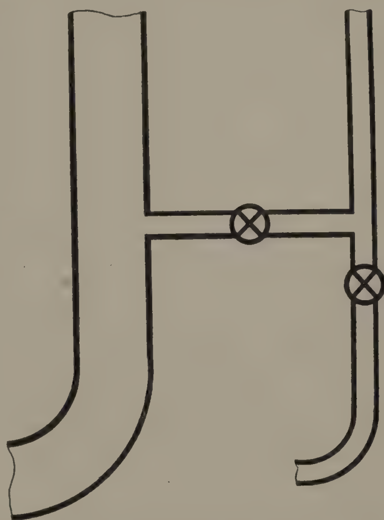

FIG. 103.—Emptying Cock connected to Soil Pipe.

2. *Possible Connections with the Drainage System.*—Where there is a danger of frost, it is common to provide a stop-cock just inside the house, by which the water may be shut off, and a draw-off cock just above it so that the pipes may be emptied. When this is really a draw-off cock it is all right, but when it takes the form of a direct connection to the drain or soil pipe,

controlled only by a stop-cock (Fig. 103), it is evident that negligence may result in charging the water pipes with drain air, if not actually with liquid. Where anything of this sort is suspected, every care should be taken to detect it.

Fig. 104 illustrates a curious possibility (actually recorded) of water pollution. Two sinks were fixed one above the other. Each had a "swan-neck" tap —that is, the delivery pipe wrought on a swivel so that it could be raised above the sink or lowered into it, as is not uncommon when space is limited and the sink is provided with a cover. Complaints were made that at the lower sink dirty soapsuds were occasionally drawn instead of clean water, and the explanation proved to be as follows:—The supply of water was poor, and the pressure failed from time to time. The user of the upper sink sometimes allowed the "swan-neck" pipe to lie forward into the sink full of soapy water, and turned the tap to get more water. If the user of the lower sink simultaneously tried to draw water, and the pressure failed at the time, the contents of the upper were transferred by syphonage to the lower. This of course is an extremely exceptional case, but it illustrates the need of investigating every possibility of contamination.

Fig. 104.—A Method of Polluting the Water Supply.

3. *Action on Lead.* — This is a question outside the province of the engineer, but it is his duty to consider the possibility, and if necessary to advise that a chemist should be consulted. He may further require to take samples for chemical analysis.

4. *Outside Contamination.*—In a private supply, it may be necessary to investigate the source, and to judge as to the chance of contamination from cultivated fields, cattle, or

vegetable growths, as well as from sewage. Water derived from surface flow or shallow wells in the neighbourhood of houses or arable land is always to be gravely suspected, and so-called "springs" may be little more than subsoil drainage. In cases involving any doubt the engineer's observations should be supplemented by a chemical or a bacteriological examination, or both: and the engineer or inspector who takes the samples must be aware of the proper method.

Sampling Water. (A) *For Chemical Analysis.*—Use a Winchester quart bottle; obtained preferably from the chemist who is to make the analysis, who will in that case see that it is chemically clean before being handed over. Rinse it out once or twice with the water to be sampled, then fill and stopper it. See that it is properly labelled with the description, date, &c., and have it conveyed to the analyst without loss of time, and in such way as to preclude any chance of tampering with it.

(B) *For Bacterial Examination.*—In this case a proper sampling equipment is essential. It consists of one or more stoppered bottles, usually of 4 ozs. capacity, enclosed in a double zinc box. The space between the two layers of zinc is to be filled with ice. Everything is sterilised before use, and in taking the sample great care is necessary that no germs of any sort (except those which may be in the water itself) gain access. The lips of the bottles and the under part of the stoppers must not be touched by the hand, and they should be exposed to the air as little as possible. Whenever the bottles have been filled they are placed in the ice box and sent at once to the laboratory. The quality of the water is judged largely by the number of organisms which are found in a given quantity of water. In favourable circumstances these may multiply with great rapidity, and the object of the ice is to impede this multiplication, so that the sample may reach the laboratory in as nearly as possible the condition in which it was taken. Speed in transmission is obviously of great importance, and it is very desirable that the sample should be in the hands of the analyst at such a

time that he can deal with it immediately, and not so late that it is left over till the following day.

Reporting.—The necessary information having been obtained, it must then be put into form. If the object is to convey the information to a person who has to consider and act upon it, the form will be a "report." A sanitary official may have to produce instead a "notice," which will be considered later. The report will naturally begin with a statement of the facts that have been discovered, arranged in some definite order. A convenient form is to give a description of the drains and traps accompanied by a plan more or less carefully drawn—it may be only a rough sketch, or it may be a finished scale drawing. Then the soil pipes, which may be identified by numbers or letters marked on the plan, and explained further by diagrams showing their connections, are described. The diagrams are practically a clean copy of the notebook diagrams indicated in Fig. 102. Next follow the waste pipes, and then the individual fittings. In this connection it is necessary in the case of a large house that the inspector should note the different rooms which contain fittings in such a way that not only can he himself identify them on his notes and plan, but that also they will be readily identified by those occupying the house. For instance, "the blue dressing-room" may be quite clear to the latter, but very vague to the inspector himself after a day or two; while he would readily understand "the dressing-room in west wing first floor."

Next would follow the result of any tests; any details which seemed to be of importance: and finally the proposals for improvement.

When the system is not good enough as it is, but perhaps not bad enough to need a complete reconstruction, there are many points calling for consideration, in addition to the actual condition of the work. The following may be taken as two extremes—on the one hand the examination is made at the instance of a tenant for a short period, and no disturbance is wanted beyond the minimum which is essential to prevent risk; on the other, it is made at the instance of a

proprietor of ample means, who wishes everything to be not only safe but thoroughly up-to-date and convenient. Again, matters may be complicated by a bargain (sometimes very vague and unsatisfactory) made between the owner or his agent and the tenant; it is not uncommon, for example, to find that a house has been let subject to the condition that the drainage system is to be "smoke-tight," and this may be an awkward stipulation for the person to whom the matter is referred. Is the system "smoke-tight" if no smoke can be detected escaping, even if it is perfectly certain that the smoke escapes freely at some places which cannot be discovered? It is often maintained that it is, but it would be very unwise to accept such a result as satisfactory. In such a case the best course is to use a smoke machine fitted with an indicating drum (Fig. 92, p. 200) and to condemn the system without hesitation if it is not possible to lift the drum by pumping —care of course being taken that all authorised outlets have been sealed. If the drum rises, and falls at once when pumping is stopped and the valve shut, it is evident that there is an escape of considerable magnitude, and the report must say so. If the drum takes, say, a couple of minutes or more to settle completely down, it is safe to assume that the escape is very minute; and if careful search fails to reveal any trace of smoke in the house it is reasonable to report that, while it is evident that the system is not absolutely tight, any escape is very small, and no trace of it could be detected in the house; and that it does not seem to be such as would involve any appreciable risk.

It is seldom wise to advise patching. If a drain is bad, it must be exposed; and the cost of the exposure is a large item in any repairs. Unless the defects are very trifling, it is seldom true economy to patch them up. The result of patching up a defective stoneware drain is very seldom satisfactory; and as in most cases a new drain might permit of straightening the drain, and perhaps correcting the sizes and giving branches of proper angle, it is usually right to recommend this. It is extremely unsatisfactory to follow up a defective drain length by length; when

this is once begun it is difficult to stop, and very often the cost incurred would have provided a completely new drain instead of an old one patched. The expert who advises the complete rooting out of old work will no doubt get hard names, but he will get just as hard names if his well-meant attempts at economy are found to be of no effect—and in the latter case he will deserve them. If therefore he is satisfied that the drainage is such that it cannot be made right by any means short of reconstruction, his clear duty is to say so; and having done so, he will be well advised to have nothing to do with any tinkering that may be undertaken if his advice is not followed. If he advises that a certain minimum of work is necessary, and an attempt is made to get off with less, he is wise to wash his hands of the work. It is anything but pleasant to hear that a certain bad system of drainage is being represented as having been put in order under his supervision, even if the only foundation for the statement is that he has condemned it; it is a good deal worse if, by taking any part in overlooking the pretended overhaul he has made it possible for his name to be truthfully associated with the result.

General Conclusions in Report.—Having described the different parts, and the result of any tests, it may be useful to give a general indication as to the conclusions to be drawn. For instance, "The system is modern and in good condition; the defects which were noted are trifling and can readily be put right." "The system is not recent, and while no very serious defects were actually seen, there is grave suspicion that the underground drain is not satisfactory." "The system on the whole seems to be good, but some decided defects were found, and these rendered it impossible to have a satisfactory test. Until these have been put right and a further test applied, it is impossible to say whether or not further defects exist." "Certain defects were found which tend to show that the general condition is not good. It is evident that considerable renewal is needed, and it would be well to make a further investigation by opening up the ground before deciding what should be done in the way of repair. It is not improbable that reconstruction

will be desirable." "The whole system is out of date and in bad order. It is obvious that complete reconstruction is the proper course to adopt."

Recommendations.—The report will naturally conclude with advice as to what work is needed to put the house into proper order, and all the circumstances of the case must be taken into account. The standard underlying the recommendations, however, should always be a high one, and if anything is suggested other than the highest possible standard, it should be for some special reason, and that reason should be stated. Unless in the case of a report made to one whose interest is temporary, such as a tenant for a short period, it is desirable to indicate what is required to make the whole system first-class. Possibly there may be certain parts of it which might reasonably have some years of useful life: this might then be stated; and it might be proper to conclude with a statement that, while certain work should be done at once, certain other parts might reasonably be left over till some indeterminate time. If, however, any work which might of itself remain for some time needs to be disturbed in the execution of the more pressing work, it is usually best to renew it also. It is seldom wise, for instance, to replace old fittings, however good they may appear to be, when they have been removed to admit new pipes. The cost of such replacement is usually a substantial proportion of the cost of putting in new fittings, and the actual value is very small. If financial considerations prevent the complete carrying out of the whole work at once, it is better to do one part thoroughly and leave the rest alone.

Cost.—It is usually expected that such a report should give some indication of the probable cost of carrying out the proposed work. The ability to do this is largely a matter of experience, but it should be borne in mind that in work of this kind there is a much greater chance of unforeseen extras than in the construction of entirely new work. The usual engineer's allowance of 10 per cent. to cover contingencies may be much too small, and the safest plan is for the engineer

to estimate as fully as he can what each part of the work is likely to cost, adding liberally to each part to cover the odd work which he knows of but does not detail, and thereafter to add at least 10 per cent. It should always be borne in mind that "contingencies" are the really unforeseen parts of the work, and not the numerous little details which the engineer ought to know will be necessary, although they are individually too small to appear in his estimate of cost.

In the case of a tenant who wishes to know whether or not the house is safely habitable, it is sometimes very difficult to draw the line. "Would you occupy the house yourself" is frequently suggested as a test, but it is scarcely conclusive. An expert may see and understand the risk, and may conclude that it is so small that he would take it: but he may not be justified in saying that there is none. His duty is to point out that the risk is there, and then to indicate whether or not he thinks it may be taken. The most difficult case is when no part is extremely bad, but when nothing short of reconstruction would make it really good. The choice lies between advising the prospective tenant to leave the house alone, or advising that the risks are such as he may reasonably take. The one course may involve the tenant in trouble and possibly litigation, while the other may be disastrous if anything goes wrong.

Another case is when the tenant is actually in the house, and has for some reason come to suspect that the drainage is not as it should be. The inspection reveals defects, and the question arises, Is it necessary to leave the house? No one would advise such an extreme course unless (1) the defects could not be put right without great inconvenience or some danger, or (2) the proprietor refused to put them right.

Such questions involve matters not of engineering alone, but of medicine and of law. It is not a part of an engineer's business to advise on either, and he will be wise to avoid statements which seem to do so. He is quite within his province in pointing out defects, advising that they should be remedied, and advising further as to the best method of remedying them. But if he is asked whether certain defects are dangerous to

health, he should confine himself to the general statement that they are such as are usually considered dangerous, but that it would be well to get a medical opinion on the facts which he has ascertained; and if necessary a legal opinion as to what should be done in the face of the facts. That is to say, the engineer should give his own facts, and the medical or legal application of these only so far as these are matters of general knowledge. An expert in any branch of engineering is sure to acquire by experience a very considerable knowledge of "case law," and his advice in consultation with a lawyer may be of great service: but he had better let the legal advice—even if he inspires it—come from the man whose business it is. Otherwise he runs considerable risks in various ways, legal risks among the number.

One legal point may be mentioned. It frequently happens that an engineer's report is detrimental to the interests of someone. He may, for example, be employed to report on the drainage system of a house, and an adverse report may produce threats of "legal proceedings." These may be entirely disregarded. It would be necessary for the aggrieved party to prove malice, even if a mistake should happen to have been made. An engineer or inspector, therefore, who carries out his duty in good faith and with ordinary care, need not worry about the result. Of course, if he is in the habit of making mistakes, his professional reputation will probably suffer, but that is another matter.

While the report is "privileged," it should avoid any needless offence. An unpleasant truth must be told, but it should be told in the most courteous and guarded way possible. There is nothing to be gained by treading needlessly on the toes of parties interested, and the personality of the writer may make a report either a pleasant or an offensive document —saying the same thing in either case. The facts should be stated without fear or favour, but not without consideration.

Notices.—Sanitary inspections so far have been treated from the standpoint of the private practitioner, employed to give an expert report to a client. The other case, where the inspec-

tion is made by the officer of a local authority, is of no less importance, but must be treated in a totally different fashion.

The standard is not what the official believes to be desirable, but what the interests of public health require. He is not advising a client who is presumably more or less willing to have his property put in good order, but he is intimating a demand—addressed perhaps to a most unwilling proprietor—that certain work which he considers necessary must be done, and done forthwith. The demand may or may not run in the name of the officer who made the inspection, but in any case he is responsible both for the facts stated in the notice, and for the improvements demanded. The inspection follows the lines already described, and the notice probably takes the form of (1) an intimation that certain defects (specified as concisely as possible) exist; (2) a brief description of the required remedy; and (3) a demand that the remedial works should be carried out within a specified time, with an intimation of the penalty in case of failure to do so.

Such a notice can take no cognizance of the fact that the work is out of date, or in any other way unsatisfactory, unless the defects amount to a statutory "nuisance," or otherwise contravene the statutory requirements. The inspector, therefore, has to be very careful that not only are his facts correctly stated, but that these facts are sufficient to warrant his interference: and that the remedial work proposed is such as he is entitled to demand. This is defined by public and private Acts of Parliament and by bye-laws and regulations made under the powers conferred by these Acts. The legal aspect of these notices, and the action which may be taken by the local authority if they are not obeyed, are outside the province of sanitary engineering.

CHAPTER XXIV

SEWAGE DISPOSAL FOR ISOLATED HOUSES

THE scope of this volume ends at the point where the house drain is connected to the sewer. The conveyance of sewage to the place of disposal, and the works required for its disposal, are dealt with elsewhere. But in the case of isolated houses there are no sewers, and the disposal works (if any) must be provided by the individual. While, therefore, it would be out of place to deal at any length with this question, a brief reference to the means which may in such cases be adopted may naturally be included.

The larger mansions and institutions require works similar to those required for villages, and may be left out of consideration. But there remain mansions of moderate size, small institutions, and a great multitude of isolated buildings which, though big enough to cause pollution, are too small to carry on successfully anything but the simplest methods of treatment.

The size of such houses varies very widely, and other conditions are no less variable. The natural outfall may be on an open and unfrequented seacoast, or, as the other extreme, it may be a small inland stream used further down for supply purposes. The nature of the occupancy may provide plenty of unskilled labour—a poor-house, for example—or it may be such that all labour has to be specially brought in: and the isolation may be likely to endure for ages, or the house may be the pioneer of a rapidly developing district. Altogether, it is impossible to do more than give general suggestions, to be applied to the circumstances of each individual case.

It it almost inevitable that the management will be "unskilled"—that is, it will not be looked after by an expert as a large work would be; "unskilled" does not necessarily

mean unintelligent. Sometimes the works are in charge of a mechanic or gardener who can get expert assistance when required, but more frequently the responsibility is laid on one who has neither expert knowledge nor the chance of consulting anyone who has. The result is that many well designed systems are complete failures.

Where constant intelligent attention, with occasional skilled advice, is not available, the simplest possible arrangements should be adopted. Fifty per cent. of purification maintained with fair regularity is better than a nominal 80 or 90 per cent., with the system out of order most of the time. So long as no actual nuisance is produced, and the purity of potable water is not endangered, a very rough-and-ready system may be tolerated in the case of the smaller houses, the quantity of sewage being so small that the uncontrolled action of natural agencies will do most of the work.

Oxidation.—Purification cannot be completed without oxidation, and the oxygen must come either from air or water. Tank processes alone are therefore incomplete, although they may often be justified by the considerations just mentioned. When it is said that the sewage is to be disposed of "by means of a septic tank" as if that ended the whole matter, one of two things is fairly certain—either that the phrase is loosely applied to a process of which the tank treatment is only a part, or that the popular conception of a septic tank is being exploited to justify what is simply a cesspool. The cesspool in certain circumstances may be quite legitimate.

Leaking Cesspools used to be a very popular mode of sewage disposal. A pit excavated in porous ground, the sides held up by rough and open building, and the whole covered in and buried, might get rid of all the sewage for a long time. Its danger was that the liquid escaping from it might pollute the subsoil water, not only in the immediate neighbourhood but even at a considerable distance; and, as the class of soil which made such a cesspool practicable was exactly that which made shallow wells a convenient source of supply, such cesspools

were seldom justifiable. They tended gradually to choke up by the deposit of solid matter which was left behind while the liquid escaped.

Retentive Cesspools consist of a built box, usually of brick and cement, covered with natural flagstones or concrete. The oldest form had a tongue or "dipstone" in the centre (Fig. 105), and the whole arrangement was intended rather as a trap than as a means of sewage disposal. It was known as a "mason" or "dipstone" trap, as well as by the name of "cesspool." It was often used in conjunction with built drains,

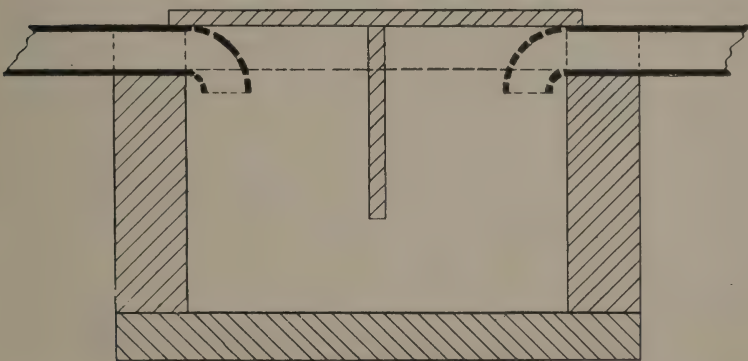

FIG. 105.—Cesspool.

and the deposit which took place in these drains and in the cesspool, and the putrefactive solution of that deposit, made the resulting liquid much clearer than the original sewage. As a trap it was very ineffective, as gases could usually pass with great freedom between the dipstone and the cover. When pipe drains came into use, the trap was made fairly effective by adding a submerged inlet, and sometimes an outlet as well, these being formed by bent pipes as shown by dotted lines. The improved system did not clarify the sewage so much as did the old: there was no longer the same deposit in the drains, and the more concentrated flow from and into the pipes caused more scour in the cesspool.

Septic or **Scum** tanks are based on these old cesspools, but an effort is made to encourage deposit and prevent scour. Many different methods are adopted, the simplest being merely one or two scum boards to allow the lighter matters to gather undisturbed on the surface, with perhaps a dwarf wall to give a lodgment for the heavier matters or sludge in the bottom (Fig. 106). The claims made on behalf of the septic tank, and especially the claim that it abolished sludge, have not stood the test of experience, even in works where the tanks were scientifically constructed and skilfully supervised. Still less is it so with the ordinary household variety; but what with the matters which are actually dissolved, those which

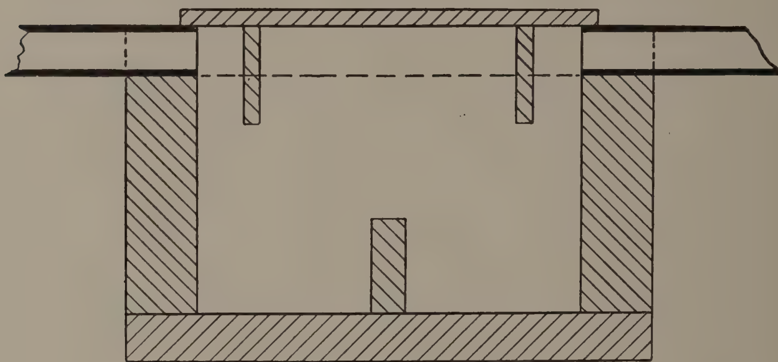

Fig. 106.—Modified Cesspool.

pass through in a fine state of suspension, and those which accumulate in the tank and are removed from time to time, a useful amount of clarification may be obtained.

The "grit chamber," which in town sewage works serves to keep road detritus out of the main tanks, is not needed for private works, unless when road washings to a considerable extent enter the drains.

The size of such a tank is usually sufficient to hold about three-quarters of the daily flow of sewage, not including rain-water. (It is often desirable to exclude rain-water entirely, and as a rule this can easily be done.) A depth equal to the width (up to six or eight feet) and the length about three or four

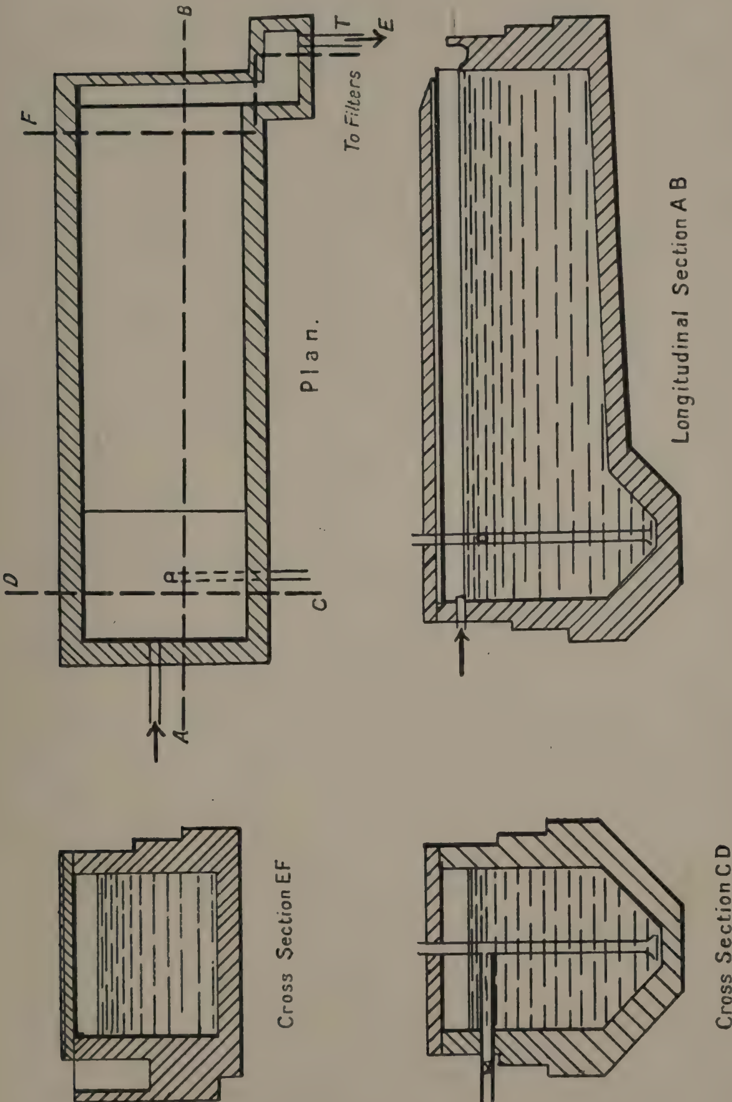

FIG. 107.—Sewage Tank.

times the width are convenient proportions. It is well to design the tank for easy removal of sludge, and for the best possible clarification of the liquor. Fig. 107 shows such an

arrangement. Most of the sludge is deposited in the deep end of the tank, and when the valve on the horizontal pipe is opened, the pressure of the sewage forces the sludge out through that pipe. In the figure a single tank is shown, but in most cases a twin tank is desirable, so that one may be off for repair or cleaning.

Tank Liquor.—This name is now applied to sewage which has received this tank treatment. It is loaded with putrescible matters, and can only be completely purified, as has already been pointed out, by some process of oxidation. This process may consist in running it into a large volume of pure water such as a river or the sea, in running it over or through land, or in one of the more concentrated appliances known as sewage filters.

Discharge into Water.—There is no objection to this in the case of a solitary house on the shore. Even on the open shore, however, a nuisance may be produced by a number of houses, and enclosed waters have a limited power of oxidising sewage. The discharge of sewage matters into streams is illegal, though often unchallenged when the quantity is trifling, and especially when some more or less effective preliminary treatment is used. When the stream has a volume of 50 to 100 times or more that of the sewage, it is unlikely that any actual nuisance will result.

Land Treatment.—(a) Surface irrigation. The usual estimate is that an acre of suitable land will deal with the sewage of about a hundred persons. This gives room for changing the place of application from time to time. The risk of nuisance is not negligible, and although the result as regards effluent may be very satisfactory, a good deal of attention and care is necessary to get such a result. The system is not now very often adopted.

(b) Subsoil irrigation. This is very similar to the foregoing, except that the tank liquor is led in open jointed pipes just under the surface. It escapes from the joints into the soil, and is

thus brought within the reach of roots and of the microscopic life of the soil. The pipes have to be taken up and relaid from time to time, as they gradually become obstructed by the deposit of suspended matters and the entrance of roots. When this is taken into account, the area provided should be much the same as in the last case: but when this method is adopted for temporary purposes, it may be possible to make a considerably less area serve. This system is often useful in the development of building estates, before the district has sufficiently developed to be ripe for public sewage works.

Filtration.—There are two recognised methods of filtration, (a) by contact beds, and (b) by percolating filters.

Contact Beds.—These are tanks filled with "filtering medium." The liquid to be filtered is run into the tanks, filling up the interstices, and is allowed to remain for some time, usually about two hours, in contact with the medium: hence the name. It is then run off, and the beds are allowed to stand empty for some time. "Empty" means, of course, without liquid, for the medium remains, and the net or liquid capacity of the contact bed is at best only about one-third of the gross capacity of the tank. Each bed may go through its whole cycle of operations—filling, standing full, emptying, and standing empty, about three times in twenty-four hours, so that it can deal with sewage each day to about its gross capacity—so long as it has not lost any of its original net capacity.

The action is that the particles of medium become coated with a film in which microbes grow abundantly. It takes some time for this condition to be established, during which time the beds are said to be in process of ripening. When the ripened bed is filled with tank liquor, the microbes act upon the organic matter and oxidise it. During the process of emptying, the falling liquid draws after it a fresh supply of air, and the bed is thus supplied alternately with sewage matter and with oxygen. In small installations it is inevitable that the action should be automatic, and the most common

arrangement is to have a dosing tank, whose capacity is the same as the net capacity of one contact bed, and to discharge the contents of this tank into the bed by means of a syphon which comes into action whenever the liquid in the dosing tank reaches a predetermined height. Partitioned off from the contact bed is another syphon, with a small opening (controlled by a tap) through which the liquid in the contact bed slowly enters the syphon chamber. The tap is so adjusted that the chamber is filled and the syphon started after the lapse of the time which is thought best for "contact," and the bed is emptied by the discharge of the syphon. Two beds working in parallel are better than one of larger capacity. Sometimes a second contact bed is provided, the liquid from the first being discharged into the second instead of direct into the outfall; the reason being that single contact does not produce a degree of purification equal to that given by the rival process of percolation.

The contact beds have the advantage that they get over all difficulty of distribution, which is the trouble with percolating filters. On the other hand, they are not so effective size for size, and as waste matters gradually gather in them, their net capacity gradually diminishes, and they need from time to time to be emptied and the material washed and screened. Further, the somewhat complicated apparatus required for timing their action is very apt to go out of order. Altogether, they may be said to have been superseded by the percolating type.

Percolating Filters.—These depend for their effective working on the fairly uniform distribution of the liquid over their surface. They are in their simplest form simply "bings" of filtering material with some means of sprinkling the sewage or tank liquor over them. Three methods may be mentioned :—

Tipping Trough.—The filter is rectangular in form, and a trough into which sewage flows from the tank runs along its length. The trough is pivoted (Fig. 108) so that when filled

it tips over and allows the sewage to flow over one side of the filter, at the same time coming into position to receive the flow for the other side. If the filter surface is formed of comparatively fine material, such as coarse sand, and if it is raked over occasionally to keep its porosity fairly constant, that method of distribution does fairly well on a small scale.

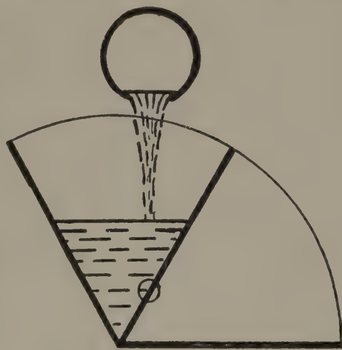

Fig. 108.—Tipping Trough.

Dripping Trays.—These, invented by Mr. Stoddart of Bristol, have been largely used. The trays are corrugated, and the liquid flows into the troughs of the corrugations. The ridges are notched, so that the liquid overflows here and there, and trickles off the bottom of the corrugations. The trays are understood to be laid dead level. It is by no means easy to maintain uniform distribution, though on a small scale occasional brushing and general attention should secure a fair uniformity. In some circumstances the exposure of the considerable area of liquid may be offensive, while the trays shield the filter from light and air, which ought rather to be freely admitted. The merits of the system are: (1) its great simplicity, and (2) that it requires very little fall. Fig. 109 is from a working plan and section of an installation of this sort.

Revolving Distributors.—The "Fiddian" or "water-wheel" distributor is a type well suited for such small installations as are meantime under consideration, in any case where it will receive reasonable attention. It consists of a long water-wheel, pivoted at the centre of the filter and resting on a rail at the outer end. The liquid is fed into the buckets on the wheel, thereby causing it to revolve. This has the double effect of pouring out the sewage over the surface and causing the apparatus to travel gradually round about its central

pivot, the wheel resting on the outer rail acting as a driving-wheel. This distributor is more elaborate than either of the others, but gives a much more uniform distribution. It

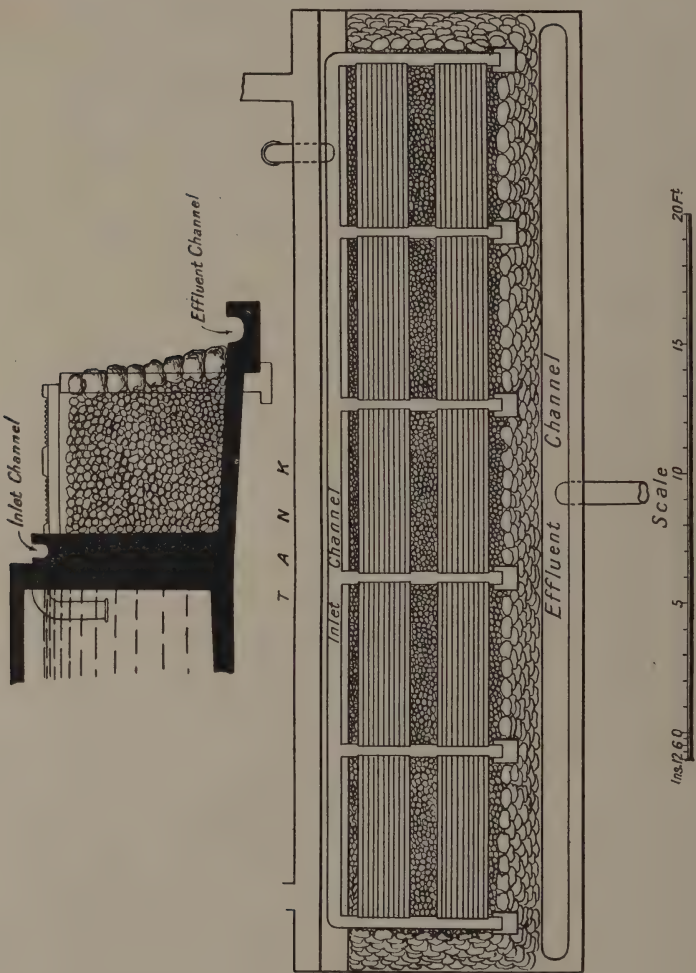

FIG. 109.—Distribution by Dripping Trays.

would be out of place for the smallest systems, but for a population of 40 or 50 or over it might reasonably be adopted. The illustration (Fig. 110) is that of a hospital installation

put in on the advice of the author, and it is so arranged that when the flow is small it is passed through two filters, whereas in wet weather the flow is divided between the two.

Size of Tanks and Filters.—It will frequently happen that installations for isolated houses do not need to follow the strict rules of economy that are inevitable in public works,

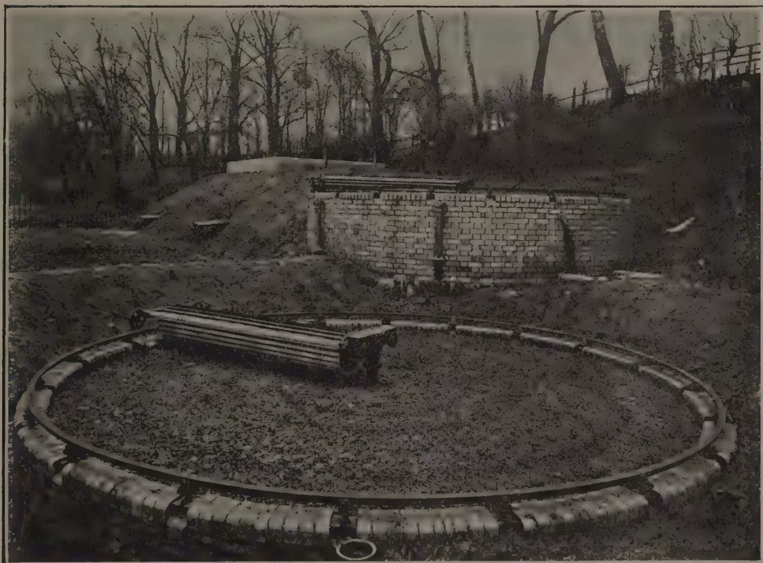

FIG. 110.—Fiddian Distributors.

but care in design is none the less needed. Tank accommodation in excess of what is needed is not only useless, but hurtful, as it retains the sewage too long and allows it to become putrid and offensive. Filters, on the other hand, may with advantage be provided liberally. For instance, it would be well to allow a cube yard of filtering material per individual, while in a large sewage work one cube yard for two or even three might be enough.

Drainage.—Good drainage is important, both to allow the filtered liquid to escape and to allow air to enter freely.

Provisionshould be made so that air can pass with freedom through the bottom of the filter, and a false floor, or drainage covering the whole area, is better than drains at intervals.

Filtering Medium.—The required qualities are strength (to avoid being crushed) : durability when exposed to the action of water; and fair roughness of surface (to give lodgment to the bacteria). The substances most commonly used are :— Clinker from iron works or from destructors, over-burned brick, slag, saggars (the broken up shells in which porcelain has been fired), broken granite or whinstone, and gravel. Of these gravel is too smooth, and while granite or whinstone are better in that respect, they are inferior to slag and clinker. On the other hand, granite and whinstone are much more durable. The cost at the particular place is an important element in determining the choice.

Size of Filtering Medium.—The filtering medium for percolating filters may range from three-inch lumps down to half-inch or even quarter-inch. The weaker the liquid, the smaller the pieces may be. Where the primary distribution is by tipping troughs, and where, therefore, the top surface must act as a further distributor, a much finer surface layer is needed than when the distribution is completed by the time the liquid falls on the surface, hence the coarse sand surface already suggested for such a case. In other cases it is not desirable to have the surface so fine, but in no case should anything be finer than the surface layer. Careful sizing of the material, so as to have layers increasing by small gradations from top to bottom, is scarcely needed; but a layer of coarse lumps over the bottom is desirable to facilitate drainage.

APPENDIX

Note A. (p. 23).

The tests, which were made in conjunction with Professor Longbottom of the Royal Technical College, Glasgow, were as follows :—

Stoneware and fireclay pipes, each bearing the brand of a well-known firm, and of apparently first-class quality, were subjected to internal hydraulic pressure, and to a crushing load in a Buckton machine. The fireclay pipes were of the kind known as "extra glazed." The object was to determine: I. The internal pressure required (a) to produce sweating, and (b) to burst the pipe; and II. The load required to produce (a) the first crack, and (b) complete smashing. For this test the pipes were placed horizontally between pitch-pine blocks, about 14 inches long—slightly grooved to fit the curve of the pipe.

The results were as follows :—

Bursting Tests.

Pipes tested.	Sweating commenced.	Pipe burst.
		lbs. per sq. in.
Fireclay, 4-inch diam. . . .	none	380
Stoneware ,, ,, ...	65	200
,, ,, ,, ...	55	220
Fireclay, 6-inch ,, ...	200	*250
Stoneware ,, ,, ...	110	150
Fireclay, 9-inch ,, ...	none	†40
,, ,, ,, ...	,,	105
Stoneware ,, ,, ...	about 100	100
,, ,, ,, ...	under 100	150

* The pipe did not burst, but owing to end leakage no higher pressure could be got.

† It is probable that this pipe was strained by the end pressure of the testing machine.

CRUSHING TESTS.

Pipes tested.	Cracked.	Smashed.
	lbs.	lbs.
Fireclay, 4-inch diam.	3,627	3,661
Stoneware, ,, ,, ...	1,817	1,976
Fireclay, 6-inch ,, ...	2,511	2,677
Stoneware, ,, ,, ...	1,624	2,098
Fireclay, 9-inch ,, .. .	3,833	4,193
Stoneware, ,, ,, ...	2,583	3,325

The figures for 4-inch and 6-inch pipes were the average of two specimens. The figures for 9-inch were from single specimens.

In most cases the stoneware pipes sweated freely at a pressure much below the bursting pressure. The fireclay pipes had a higher average bursting pressure, with little or no sweating. The resistance to crushing was about 50 per cent. more in the fireclay than in the stoneware; and this was not due to any difference in thickness, which was inappreciable in the case of the 4-inch pipes, slightly in favour of fireclay in the 6-inch pipes, and slightly in favour of stoneware in the 9-inch pipes.

The stoneware pipes were much superior in appearance, finish, and regularity of shape. The fireclay pipe which burst at 40 lbs. was irregular at the ends, and as great force had to be used to get its ends tight in the testing machine, it is probable that it was thereby strained. The extra or "slip" glaze on the fireclay pipes had, no doubt, much to do with the freedom from sweating, and produced an inside surface much smoother than that of the stoneware pipes.

NOTE B. (p. 38).

The calculation would be as follows:—

How much water will be carried by a 4-inch pipe, running full, the gradient being 1 in 40?

Q = Quantity in cubic feet per second = $V \times A$.
(V = Velocity in feet per second. A = Area in square feet.)

$$V = C\sqrt{R\,S.}$$

(R = hydraulic radius, which in this case is 1 inch, or $\frac{1}{12}$ of a foot. S = gradient, which in this case is $\frac{1}{40}$.)

C is the figure which it is suggested in the text may, for a 4-inch pipe, be taken approximately as 62, but which might be calculated as follows, taking the gradient as given above and the coefficient of roughness as ·013.

$$C = \left\{ \frac{41{\cdot}6 + \dfrac{1{\cdot}811}{n} + \dfrac{{\cdot}00281}{S}}{1 + \left[\left(41{\cdot}6 + \dfrac{{\cdot}00281}{S}\right) \times \dfrac{n}{\sqrt{R}}\right]} \right\}$$

$$= \left\{ \frac{41{\cdot}6 + \dfrac{1{\cdot}811}{{\cdot}013} + \dfrac{{\cdot}00281}{\frac{1}{40}}}{1 + \left[\left(41{\cdot}6 + \dfrac{{\cdot}00281}{\frac{1}{40}}\right) \times \dfrac{{\cdot}013}{\sqrt{\frac{1}{12}}}\right]} \right\}$$

$$= \frac{41{\cdot}6 + 139{\cdot}308 + {\cdot}112}{1 + [41{\cdot}6 + {\cdot}112]\ {\cdot}013 \times 3{\cdot}464}$$

$$= \frac{181{\cdot}02}{2{\cdot}878} = 62{\cdot}88.$$

Taking C as 62, then $V = 62\sqrt{\frac{1}{12} \times \frac{1}{40}} = 2{\cdot}83$, and $A = \pi r^2 = 3{\cdot}14 \times (\frac{1}{6})^2$ $= {\cdot}087$ square foot. So $Q = 2{\cdot}83 \times {\cdot}087 = {\cdot}246$ cubic foot per second. Multiplying this by $6\frac{1}{4}$ gives 1·537 gallons per second.

If n had been taken $= {\cdot}011$, the value of C would have been 79·7. The velocity would have been 3·64, the cubic feet per second would have been 0·317, and the gallons per second 1·98.

This example therefore shows not only how the calculation is made, but also the futility of expecting to get precise results from any such calculations. The value of n has to be filled in according to the judgment of the calculator, and the selection makes a material difference in the result. The above figures are carried to a degree of minuteness far beyond that required for any practical purpose, merely to illustrate the method.

It might be added that a pipe will not run absolutely full unless under pressure, as its carrying capacity is greater when nearly full than when quite full. This is due to the fact that the hydraulic radius is greater when the pipe is not quite full.

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